SCIENCE OF DAIRYING

A TEXT-BOOK FOR THE USE OF SECONDARY
AND TECHNICAL SCHOOLS

BY

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PREFACE

Although the scientific study of Dairying is quite modern, there is already a movement to place Dairy Science upon a footing with Botany, Zoology, and other well-recognized sciences. Especially is this the case in certain of the colonies, where the dairying industry has assumed great importance; in several instances Dairy Science has been made a subject for Public Service examinations, and placed in the curricula of high and technical schools.

This has led to a demand for a suitable class-book; but although there are many excellent works dealing with certain branches of Dairy Science, such as milk-testing, cattle-breeding, and dairy chemistry, instructors have hitherto been hampered by the absence of some brief but comprehensive text-book embracing the whole subject. The author hopes that this volume will meet that demand.

Individual practical work should form a prominent part of the course. The various tests and laboratory experiments described in the text are intended to be performed individually by the pupils. Students of ordinary secondary schools have not the advantage of living under actual farm conditions as have those

of an agricultural college, but they can do a great deal, especially in rural districts, by co-operation with dairy farmers: this applies particularly to such work as herd-testing and cattle-judging.

Butter- and cheese-making, the preparation of starters, pasteurization, and cream-raising can easily be carried out on a small scale in the laboratory; and, besides the tests actually described, many experiments should suggest themselves to the reader.

It is hoped that the chapter on Dairy Arithmetic will be found to give some idea of the financial aspect of dairying; in addition to this, numerous references to "making things pay" will be noticed throughout the text. This should always be kept in view, for is it not the very *raison d'être* of Dairy Science? Indeed, it is well to remember that Dairy Science is not really a new science, but only the application of many established sciences—Physics, Chemistry, Zoology, and others—to an important industry.

The author wishes to express his sincere thanks to the New Zealand Department of Agriculture for permission to use information and reproduce illustrations from its bulletins; to Mr. E. H. Farrington, of the Wisconsin Experiment Station, U.S.A., for information on the subject of acidimetry; and to Mr. J. P. Kalaugher, Senior Instructor in Agriculture to the Auckland Board of Education, N.Z., who kindly criticized the manuscript and offered many valuable suggestions.

W. A. C. B.

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CHAPTER I.

COMPOSITION OF MILK.

The Composition of Milk. Cow's milk is a yellowish-white, opaque liquid produced by the glands of the udder.

FIG. 1.—THE COMPOSITION OF MILK.

Sugar 5.0 %. Ash 0.7 %. Water 87.1 %.
Albumen 0.7 %. Fat 4.0 %. Casein 2.5 %.

The function of these glands is to extract water and certain solids from the blood, and then to pass them down small tubes called "milk ducts" into the reservoirs, which are situated above the teats. Milk is intended by nature not for the use of man, but for the nourishment of the young calf. For this reason it contains a number of nutritive substances which make it one of the most valuable foods known. There

is as much food-value in a quart of milk as in twelve ounces of beef-steak. Average milk is composed of the following substances :

Water	87·1	per cent.
Casein	2·5	,,
Albumen	0·7	,,
Milk-sugar	5·0	,,
Ash	0·7	,,
Fat	4·0	,,

The first five constituents form "skim-milk," or milk-serum, in which tiny globules of fat are suspended.

Casein and albumen are important substances called "proteids," because they contain nitrogen, the most valuable of food elements. Several other proteids are thought to be present in milk, but not much is known of them at present, and they occur only in very small quantities.

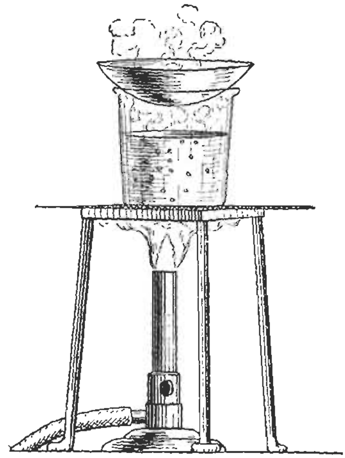


FIG. 2.—EVAPORATING THE WATER FROM MILK.

The "ash" consists of several substances which remain behind when the milk-solids are burnt. The total percentage of solids varies from about 10 to 18 per cent., but the exact amount in any particular sample of milk can easily be determined in the following manner :

Take an evaporating dish or small saucer, see that it is perfectly clean, and weigh it carefully on a delicate

balance. Pour a quantity of milk into the dish, weigh again: find the weight of the milk alone by subtracting from this result the weight of the empty dish. Then place the dish of milk over a beaker of water and boil the water until the liquid portion of the milk has all evaporated. When only the dry milk-solids remain, find their weight, and calculate what percentage of the whole milk they form.

The following will serve as an example:

	Weight of empty dish	-	= 18·62 grm.
	,, dish of milk	-	= 41·08 ,,
∴	,, milk alone -	-	= 22·46 ,,
	,, dish of dry solids		= 21·45 ,,
	,, dish alone -	-	= 18·62 ,,
∴	,, solids alone	-	= 2·83 ,,

Percentage of solids - - $= \frac{\text{weight of solids}}{\text{weight of milk}} \times 100$

$= \frac{2{\cdot}83}{22{\cdot}46} \times 100$

$= \underline{12{\cdot}6 \text{ per cent.}}$

Another way of drying the milk is to place it in an oven, but the solids must not be allowed to burn. Let us now consider in detail the various constituents of milk.

Water. Water serves two important purposes in milk. Firstly, it holds the solids in solution, or suspended in the form of minute particles, thus making them easily digestible and immediately available for nourishment, without the need of mastication.

Secondly, it serves to dilute the milk: the composition of the milk-solids is such as to render them a perfect food, but a diet of milk-solids alone would be too highly concentrated. Water, although not itself a food, is necessary to give the milk sufficient bulk to make the solids digestible by the delicate internal organs of the young calf.

The amount of water is generally about 87 per cent. of the milk, but varies from 82 to 92 per cent. The principal conditions upon which the percentage of water depends are the age of the cow, her individual character, breed, food, health, amount of water drunk, and the stage of lactation.

(*a*) *Period of Lactation.* This term denotes the time during which a cow is in milk between successive calvings. In the case of a good dairy cow it should not be less than ten months, extending from two or three weeks after calving until drying-off again. During the first three months of lactation we find the percentage of water increasing as a general rule, from about 86 to 86·5 per cent., and then gradually falling until it reaches 85 per cent. during the tenth month. Meanwhile the amount of butter-fat and other solids also varies, but in the opposite way: the milk is richest at the end of the period. Cows are sometimes milked all through the year.

(*b*) *Breed.* Breed makes a considerable difference to the composition of milk. Holstein and Ayrshire cattle give milk which contains more water than that of the Channel Island (Jersey and Guernsey) breeds, but they generally make up for the low percentage of solids by a large yield of milk.

The following table shows the average percentage of water contained in the milk of the common dairy breeds under equal conditions :

Name of Breed.	Water Percentage.
Holstein Friesian	88·2
Ayrshire	87·3
Shorthorn	85·7
Devon	85·5
Guernsey	85·1
Jersey	84·6

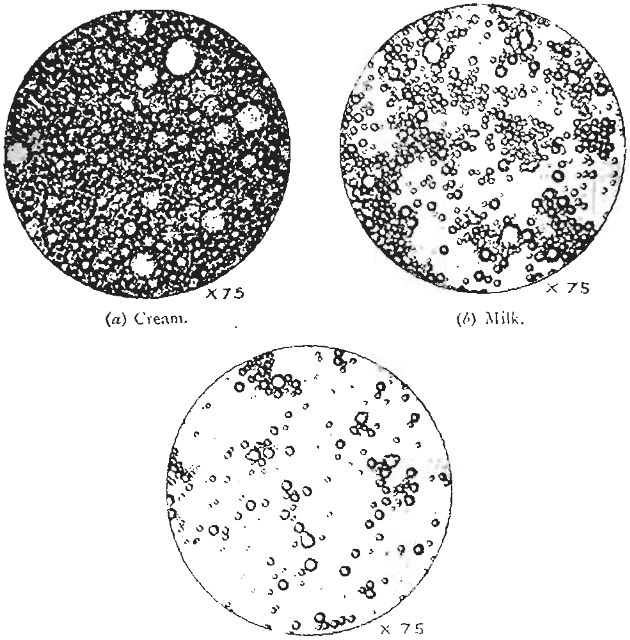
If we look at the percentage of *butter-fat* yielded by the various breeds, we find that the above order is exactly reversed. The figures given above are, of course, subject to variation on account of one or more of the many other things besides breed which influence the composition of milk.

Milk-Solids. The milk-solids are milk-fat or butter-fat, casein, albumen, milk-sugar or lactose, "ash," and several unimportant substances which occur in minute quantities. The milk-solids are frequently classified as "fat" and "solids-not-fat." The percentage of total solids in milk varies just as the water percentage varies, but the proportionate amounts of the various solids are remarkably uniform ; for example, we never find whole milk containing the normal amount of solids-not-fat, and, at the same time, a very low percentage of fat. A high percentage of any one solid nearly always means a high percentage of all.

Milk Fat. The fat in milk is generally called "butter-fat," because it forms the principal part of butter. It is not in solution, but is present in the form of minute globules, which are said to be "suspended" in the milk. The difference between a suspension and a solution is very easily understood.

Put a teaspoonful of sugar in a glass of water ; it soon dissolves, forming a *solution*. Then mix a little clay with water in the same way. The clay will not dissolve, but divides into minute particles, which become distributed through the water in the form of a *suspension*. If allowed to stand, these suspended particles of clay gradually fall to the bottom. The sugar, however, will always remain in solution.

The fat-globules in milk are transparent, yellow in colour, spherical in shape, and extremely small. They vary in size, but the average diameter is only one ten-thousandth of an inch. The size of the globule



(*a*) Cream. (*b*) Milk.

(*c*) Skim-milk.

FIG. 3.—FAT-GLOBULES IN CREAM, MILK, AND SKIM-MILK.

varies with the breed of the cow and also with the stage of lactation. Jersey and Guernsey milk contain large globules (that is, about one three-thousandth of an inch in diameter), but they are considerably smaller in the milk of Holstein or Ayrshire cows. With regard to the period of lactation, we find that during the first

few months of milking, the globules are large but comparatively few; towards the end of the period they become smaller but more numerous. Large globules are more easily separated from the milk than small ones. If we take two samples of milk, one Jersey and the other Holstein, and fill a tall glass flask with each, we find that the Jersey milk is very soon covered with a well-defined layer of cream. The Holstein globules, being smaller, rise more slowly, and the "cream line" is much less distinct than it is in the Jersey milk.

The fat-globules in skim-milk are small and comparatively few, but in cream they are large and numerous. In order to make butter, these globules must be knocked together by churning, so as to form a solid mass of fat.

Amount of Butter-Fat. The fat-globules generally form about 4 per cent. of the milk; sometimes the amount reaches 5·5 per cent. or even more, and occasionally falls as low as 2·5, these limits being most frequently reached by Jersey and Holstein milk respectively.

The chief points which influence the percentage of fat in milk are given below:

(*a*) *Individuality of the Cow.* Cows may be of the same breed, at the same stage of lactation, of the same age, and subjected to the same treatment, and yet give milk of different degrees of richness. It is an uncommon thing to find in a herd two cows whose milk-yields regularly contain the same percentage of fat.

(*b*) *Breed.* It naturally follows that those breeds whose milk contains a high percentage of water produce

milk of a low fat-content. This is shown by the following table :

Name of Breed.	Fat-Percentage.
Jersey	5·3
Guernsey	5·0
Devon	4·5
Shorthorn	4·0
Ayrshire	3·8
Holstein	3·35

(*c*) *Age of Cow.* There seems to be a tendency for the fat-percentage to decrease with each successive period of lactation after the second, but exceptions to this rule are common.

(*d*) *Stage of Lactation.* For the first three months of the lactation period the percentage of fat gradually decreases. It then commences to rise again, and continues to do so until, at the end of the period, it is considerably higher than at the beginning.

The following figures show a cow's average fat-percentages for a period of ten months :

1st month	4·56	6th month	4·53
2nd "	4·34	7th "	4·56
3rd "	4·27	8th "	4·67
4th "	4·38	9th "	4·81
5th "	4·41	10th "	5·1

(*e*) *Time of Milkings.* Leaving a long interval of time between successive milkings tends to increase the quantity of milk but to decrease its fat-percentage.

As a rule, evening's milk is a little richer than morning's milk. The reason is that the interval between the morning's and the evening's milkings is less than that between the evening's and the next morning's.

(*f*) *Portions of Milk drawn.* The first milk drawn from the udder is always very poor in butter-fat, generally containing less than one per cent.; the last portion, or "strippings," is much richer and may contain over ten per cent. The reason for this is that the largest and richest part of the milk is made *during milking*. This can easily be proved by taking four or five samples of milk at regular intervals as it is drawn from the cow. Supposing the milk to be divided into four equal portions, the results of the tests would probably be:

1st portion contains	- -	1·0 per cent. fat.
2nd ,, ,,	- -	2·6 ,, ,,
3rd ,, ,,	- -	5·35 ,, ,,
4th ,, ,,	- -	10·0 ,, ,,

The above figures show how important it is to take a sample from the *whole milking* when testing the value of a cow. As a rule, the percentage of fat in milk also varies slightly with the different quarters of the udder. A good cow should produce 300 pounds of fat in a year. The exact percentage of fat in a sample of milk can easily be determined by means of the Babcock test, which is described farther on in this book.

Casein. Casein, which forms the principal part of curd, is a white solid existing in milk, not in solution, but in a state of suspension. The particles of casein are extremely minute and cannot be seen under a microscope, as the fat-globules can. Casein is a very complex chemical compound, containing the elements carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus.

Albumen and other proteids have a similar composition and, like casein, are very valuable as foods. Casein forms 2·5 per cent. of milk and 80 per cent. of the total milk-proteids, the remaining 20 per cent. being chiefly albumen.

The casein in milk is in combination with calcium, or lime, and is kept in suspension by it. If acid is formed in the milk during natural souring, or is put in artificially, the acid separates the calcium from the casein, and consequently the casein falls to the bottom. That is why milk curdles when it goes sour.

Sulphuric, acetic (vinegar), nitric, and other acids have a similar effect. Cheese is made from the curd obtained by coagulating milk with rennet. Rennet contains certain substances known as "ferments," which curdle the milk. The action of rennet, however, is very different from that of an acid, and so is the nature of the curd formed by it. Rennet curd is properly called "calcium paracasein"; ordinary milk casein, being combined with calcium, is called "calcium casein."

About one-quarter of ordinary cheddar cheese consists of casein. During recent years, many important commercial uses have been found for casein. It is used as imitation ivory or bone in the manufacture of buttons, combs, backs of brushes, and many other articles. It is also used for putting a finish on writing paper and for making glue and paint.

Albumen. Albumen is another proteid, familiar to us all in the form of white of egg. It is in solution in milk and cannot be precipitated, or thrown down, by rennet. By first precipitating the casein, however,

and then heating the milk to about 165 degrees Fahr., albumen is precipitated in the form of a white solid; in a similar way, the white of an egg hardens when boiled. Milk utensils should be washed in warm water before being scalded, as boiling water precipitates the albumen and makes it difficult to be removed. There is very little albumen in the common cheeses, as it is not precipitated by rennet and remains in the whey. Italian cheese, which contains albumen instead of casein, is made from whey. The albumen is precipitated by heating and allowed to settle. The liquid is then drawn off, and the albumen is put into moulds. The cheese is rather tasteless, but very nutritious.

Test for Albumen. In order to show the presence of albumen in milk we require a small quantity of strong nitric acid and some whey. The whey may be prepared by adding a drop or two of rennet extract to some milk in a beaker, stirring to mix thoroughly, and just slightly warming. The casein in the milk will be precipitated by the rennet in the form of a thick curd, most of the albumen being left in the transparent liquid known as whey. Pour off some of the clear whey into a test-tube. Then let a little concentrated nitric acid flow down the side of the test-tube, so that it sinks below the whey. If albumen is present, white clouds will be formed at the junction of acid and whey.

Milk-Sugar. Milk-sugar, or lactose, forms about 5 per cent. of milk. It resembles ordinary sugar, but is not so soluble or so sweet. It is largely used in commerce for making patent foods, and in medicine for coating pills and making powders. For these purposes, lactose is obtained from skim-milk or whey.

Milk-sugar is of the utmost importance to the dairying industry, because it can be changed into lactic acid. The effect of lactic acid is to sour or "ripen" milk, and so impart a flavour to the products made from it. The lactic acid in milk is made from milk-sugar by the action of bacteria or germs. Under ordinary conditions, milk always contains large numbers of these germs, which attack the lactose and convert it into lactic acid. This is done by simply altering the arrangement of the atoms of which lactose is made. The chemical composition of lactose is represented by the formula $C_{12}H_{22}O_{11}$ (that is, 12 atoms of carbon, 22 of hydrogen, and 11 of oxygen).

The bacteria divide these atoms into four equal groups, each being one part of lactic acid ($C_3H_6O_3$). Thus:

$$\underset{\text{Water.}}{H_2O} + \underset{\text{Milk-sugar.}}{C_{12}H_{22}O_{11}} = \underset{\text{Lactic acid.}}{4(C_3H_6O_3)}.$$

Milk-sugar is used for making pure cultures of lactic acid, which are employed in the propagation of starters.

Test for Lactose. The presence of lactose in milk can easily be shown by the use of Fehling's solution. Put a small quantity of milk into a test-tube, add a little Fehling's solution, and heat the mixture until it boils. The blue colour of the solution disappears, and the liquid becomes dull red. This change of colour is due to the action of the lactose on the Fehling's solution.

If ordinary cane sugar be tested in a similar manner, it will be found to have no effect on Fehling's solution; that is, the colour of the liquid remains blue. Fehling's solution is best made and kept in two parts, which are mixed just before use. One part consists of 7 grams of copper sulphate dissolved in 100 c.c. of water. The

other contains $34\frac{1}{2}$ grams of Rochelle salt (sodium potassium tartrate) and 32 grams of caustic potash, dissolved in 100 c.c. of water. Equal quantities of the two liquids are mixed when required for use; they form a deep blue liquid, known as Fehling's solution.

Ash. The "ash" of milk is that portion which remains behind after milk is thoroughly burnt. It is dull white in colour, and forms about 0·7 per cent. of the milk. The ash is composed of a number of chemical compounds called "salts," and is an important constituent of milk because it contains bone-forming material for growing animals.

Part of the ash is dissolved in milk, and part is present in the form of a suspension. Each "salt" is a compound of an acid with a "base" or "alkali." Some of the bases found in milk-ash are soda, potash, lime, and magnesia. Hydrochloric, citric, and phosphoric acids are examples of the acids. Phosphate of lime, citrate of lime, and chloride of soda may be mentioned as examples of the salts. The salts of lime (calcium), it will be remembered, keep the particles of casein suspended in the milk.

The percentage of ash in a sample of milk can easily be determined by weighing a quantity of the milk, burning it till only a white ash remains, and then weighing the ash.

QUESTIONS ON CHAPTER I.

1. How many pounds of albumen, lactose, ash, and water are contained in 250 lb. of average milk?

2. Why does milk sour, and why does it curdle when it sours?

3. Give an account of the conditions upon which the fat content of milk depends.

4. What is meant by a "suspension"? Compare the ways in which fat and casein are present in milk.

5. Say what you know about the "ash" of milk.

6. Explain carefully how you would determine the percentage of solid matter in a sample of milk.

CHAPTER II.

PROPERTIES OF MILK.

As already stated in the last chapter, milk contains about 87 per cent. of water and 13 per cent. of solids. Some of these solids, such as lactose, are in solution. The casein, on the other hand, is distributed through the milk in the form of minute particles which are not actually dissolved, but are held in suspension. The fat-globules are also held in suspension, and on this account, milk may be called an *emulsion*. Everyone knows that fat and water will not mix, but if the fat is broken into sufficiently small particles, it will remain suspended in the liquid for some time. Such a mixture of fat, or oil, with water is known as an emulsion.

Pure Milk. The meaning of the term " pure milk " varies considerably. For legal purposes, it is generally understood to mean not merely milk which is free from adulteration, but the *whole milk*; so that, in this sense, the very poor milk first drawn from a cow cannot be called pure. Pure milk may be defined as " the whole of the milk drawn at the time of milking, free from any preservative or colouring matter of any kind."

The Specific Gravity of Milk. The " specific gravity " of any substance means the number of times

that substance is as heavy as water, bulk for bulk, when measured at a temperature of 60 degrees Fahr. If we take equal volumes of copper and water, for instance, we shall find that the copper weighs just 8·9 times as much as the water ; this is expressed by saying that the specific gravity or relative density, of copper is 8·9.

Milk is slightly heavier than water, its specific gravity being generally 1·032. A tank large enough to contain exactly 1000 lb. of water would hold just 1032 lb. of pure milk. The temperature of both milk and water is here assumed to be 60 degrees Fahr. If the milk were warmed above that temperature, it would expand, and we should not be able to get as much as 1032 lb. of it into the tank. On the other hand, if it were below 60 degrees Fahr., the volume of the milk would be diminished, and a greater quantity could be put into the tank ; the specific gravity would be higher than 1·032. Thus, it is very important to remember that the correct specific gravity is "the number of times a substance is as heavy as an equal volume of water, *measured at* 60 *degrees Fahr.*"

The specific gravity of pure milk is not always exactly 1·032, even when the milk is at the correct temperature. There are several causes which may affect it, but the variation is only very slight ; it is nearly always between 1·032 and 1·034.

Finding Specific Gravity. The specific gravity of a sample of milk can easily be found by weighing equal volumes of milk and water, and then comparing their weights, in the following way :

Place a small bottle upon the pan of a balance and add shot to the other side until it swings evenly. (An

ordinary Babcock test-bottle serves the purpose very well.) Then pour water into the bottle up to some definite mark upon the neck. Add weights to the shot in the pan of the balance until it swings evenly again. The weights which have been added will equal the weight of the water. After noting its weight, empty out the water, and refill the bottle with milk

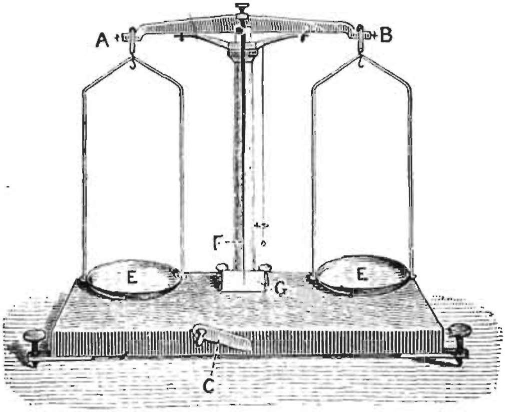


FIG. 4.—BALANCE AND WEIGHTS.

AB. Beam. C. Handle to raise beam.
E. Pan. F. Pointer. G. Scale.

up to the same mark. (Both milk and water must be at 60 degrees Fahr.) Find the weight of the milk, and divide it by the weight of the water. The result will be the specific gravity of the milk.

For example :

Weight of water to mark	-	45·63 grm.
,, milk ,,	-	47·09
Specific gravity of milk	-	$\frac{47{\cdot}09}{45{\cdot}63} = 1{\cdot}032.$

The Lactometer. The method of finding specific gravity which has just been described will not give

accurate results unless the weighing is done with very great care; it also requires a considerable amount of time. For practical purposes we generally find the specific gravity of milk by means of an instrument called the Lactometer, which gives the answer immediately and accurately. The lactometer is really a glass tube divided into three portions, and closed at both ends.

FIG. 5.—THE QUEVENNE LACTOMETER.

The bottom portion consists of a bulb containing mercury or lead shot; its purpose is to act as a weight and keep the instrument upright when placed in milk.

The middle division is the widest, and contains air to make the lactometer float. The top portion, or neck, consists of a glass tube which contains a graduated scale.

To find specific gravity, the lactometer is placed in the sample of milk. The denser the milk, the higher will the instrument float, and the lower will the surface of the milk be upon the graduated scale. For this reason, the graduations begin at the top of the scale and increase downwards.

There are several kinds of lactometers, but the principal difference between them is in the graduation of the neck.

The Quevenne Lactometer. This instrument is made to register specific gravities between 1·015 and 1·040, and is graduated so as to give readings correct

to 0·001. The actual markings on the scale, however, omit the 1·0 in each case, and show only the second and third places of decimals; in other words, the scale is graduated downwards from 15 to 40.

The New York Board of Health Lactometer. Another type which should be noticed is the New York Board of Health Lactometer. In structure it resembles the Quevenne, but the graduations are entirely different. The top of the scale is marked 0; this is the level to which the instrument sinks in water (specific gravity = 1·000). From this mark the graduations increase by 10's to 120 (specific gravity = 1·0348). The 100 mark was chosen to represent a specific gravity of 1·029, which is the lowest reading ever given by whole milk from a healthy cow. The Quevenne lactometer, it will be remembered, is graduated so as to show the actual specific gravity of milk.

Effect of Temperature. Lactometers are intended for use in milk at a temperature of 60 degrees Fahr., and if this temperature is not adhered to, the result will be misleading.

As already explained, a rise in temperature means an increase in volume and a decrease in density, or specific gravity. Consequently, a sample of pure milk, registering specific gravity 1·032 at 60 degrees Fahr., would give a lower reading at a higher temperature and a high reading at a lower temperature.

The lactometer may be used at other temperatures besides 60 degrees, but the readings then require to be corrected.

The rule is as follows: In order to find what the specific gravity would be at 60 degrees Fahr., add 0·1 to the

Quevenne reading for each degree above 60 degrees, and subtract 0·1 for each degree below. The result will not be quite accurate, but close enough for ordinary purposes.

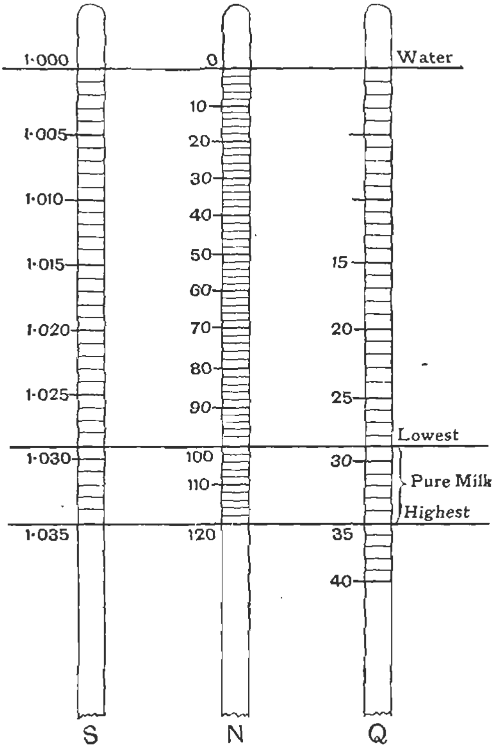


FIG. 6.—THE SPECIFIC GRAVITY SCALE (S) COMPARED WITH THE SCALES OF THE QUEVENNE (Q) AND NEW YORK BOARD OF HEALTH (N) LACTOMETERS.

For example, at 76 degrees Fahr. the specific gravity of a certain sample of milk is 1·030 (Quevenne reading =30); what would be the specific gravity of the milk at 60 degrees Fahr.?

The specific gravity at 60 degrees will be greater than it is at 76 degrees, and so we add 0·1 to the Quevenne reading for each degree by which 76 exceeds 60 degrees.

Thus the Quevenne reading at 60 degrees would be $30 + (0{\cdot}1 \times 16) = 31{\cdot}6$.

This equals a specific gravity of 1·0316.

Weight of Milk. By an Act of Parliament passed in 1878 a British imperial gallon was declared to be that volume of water which weighs 10 lb. at a temperature of 62 degrees Fahr. Since the specific gravity of average milk is about 1·032, it follows that the weight of a gallon of milk is 10·32 lb. (about 10 lb. 5 oz.) and the weight of a quart is 2·58 lb. American writers commonly state that the weight of a quart of milk is 2·15 lb. This is also correct, for the United States gallon is smaller than the British gallon, being approximately only 0·83 of it. The weight of a gallon of milk varies slightly according to the quality; poor milk is a little heavier than rich milk.

Effect of Solids on Specific Gravity. Milk is heavier than water on account of the solids which it contains. With the exception of butter-fat, the milk-solids are all heavier than water. Butter-fat is lighter, having a specific gravity of 0·936.

Although the percentage of solids in milk varies greatly, it is to be noted that the specific gravity always remains about the same. This is because the heavy solids and the butter-fat balance each other. A high percentage of casein, lactose, and albumen would cause a high specific gravity were it not for the fact that the percentage of butter-fat increases accordingly and so preserves equilibrium.

Detection of Skimming. If, for any reason, there is not enough butter-fat in the milk to compensate for the heavy solids, we find that the specific gravity of the milk is noticeably increased. In consequence of this fact, it is an easy matter to detect skimming. A specific gravity of 1·038 or more may be accepted as a sure sign that some of the fat has been taken from the milk, or that skim-milk has been added. The specific gravity of skimmed milk is often much greater than this; it depends upon how much fat has been skimmed off, and upon the percentage of heavy solids left in the milk.

Detection of Watering. Adulteration of milk by adding water can also be detected by means of the lactometer. Water is lighter than milk, and so its addition to milk lowers the specific gravity. If the lactometer shows the specific gravity at 60 degrees to be less than 1·029, it is safe to assume that the milk has been watered. The addition of cream to milk would have the same effect, but in that case the cause would most likely be known. As a general rule, a low specific gravity is a sure sign of watering. If a high percentage of fat is thought to be the reason, the question can easily be decided by means of the Babcock test, which enables us to discover the exact percentage of fat in milk.

The Double Fraud. Skimming raises the specific gravity of milk; watering lowers it. If milk be both watered and skimmed, however, the effect of the one can be made to counteract that of the other, so that the specific gravity becomes the same as that of pure milk.

This double fraud cannot be detected by the lactometer alone, but the Babcock test will reveal the low percentage of fat. This is a sign of skimming, and the fact that the specific gravity is not thereby raised suggests watering as well. The percentage of solids can then be found; if it is low, it will signify the addition of water.

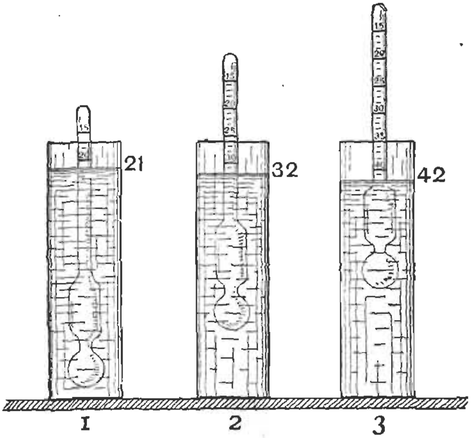


FIG. 7. THE USE OF THE LACTOMETER.

(1) Watered Milk (Sp. Gr. 1.021). (2) Pure Milk (Sp. Gr. 1.032) (3) Skimmed Milk (Sp. Gr. 1.042).

Colour of Milk. Milk possesses a pale yellowish colour, which is due to the presence of small quantities of a colouring matter known as *lactochrome*. Some breeds of cattle, such as the Holstein, give milk which is very pale in colour. The Channel Islands breeds, on the other hand, are noted for the distinct yellowness of their milk. The milk of these breeds, it will be remembered, is very rich in butter-fat, and so yellowness is popularly regarded as a sign of richness. Milk

which possesses an unnaturally bright yellow colour is to be avoided, and so also is bluish milk. Owing to the solid particles of casein which it holds in suspension, milk is not transparent.

Amphoteric Action of Milk. A large class of substances, known as acids, possesses the power of turning blue litmus red. Alkalis, on the other hand, turn red litmus paper blue. These substances which have no action on litmus are said to be neutral.

What effect has milk on litmus?

Place a blue litmus paper and also a red one in some *fresh* milk. The effect is very peculiar, for *both* colours are changed; the red paper becomes slightly blue, and the blue one slightly red. This double action is called *amphoteric*.

Effect of Heat on Milk. Milk boils more quickly than water. The reason is not that milk boils at a lower temperature, but that it requires less heat to raise its temperature than water does. As a matter of fact, the boiling-point of milk is slightly higher than that of water. Milk, however, contains a number of easily-heated solids. Consequently, if the same amount of heat is applied to equal quantities of milk and of water, the temperature of the milk will be raised more than that of the water.

Supposing that the amount of heat required to raise the temperature of a certain weight of water through a certain number of degrees is represented by 1, then 0·85 represents the amount of heat required to raise the temperature of the same weight of milk through the same number of degrees.

This is briefly expressed by saying that the specific

heat of milk is 0·85. In other words, the temperature of a quantity of milk can be raised a certain number of degrees by 0·85 of the heat which would be needed to have the same effect upon an equal quantity of water.

That is why milk boils more quickly than water.

The Milk-Yield. As a rule, a dairy-cow remains in milk for 9 or 10 months of the year, producing an average daily yield of between 25 and 40 lb. of milk during the period.

The total production of milk for the year varies accordingly; usually it is between 5000 and 9000 lb., and contains from 200 to 330 lb. of butter-fat. Many individual cows, however, have been found to produce as much as 12,000 lb. of milk in the year, with between 450 and 500 lb. of fat.

It is generally found that the evening's milk is slightly richer than the morning's, although a little less in quantity. This is because there is a shorter interval between morning milking and evening milking than between evening and morning, and experiments have proved that the shorter the intervals between milkings the richer the milk. Suppose the cows are milked at 7 a.m. and 5 p.m. This divides the day into two portions of 10 hours and 14 hours. The morning's milking thus takes place after a longer interval than the evening's, and so the richer milk is obtained in the evening. The yield of both milk and fat can be increased by milking at shorter intervals of time. In one experiment, when the cows were milked at intervals of two hours, the milk-yield increased 20 per cent., and the quantity of fat 25 per cent. If milked

three times a day, an ordinary cow can be made to produce 5 or 6 per cent. more milk than when she is milked only twice. It is very doubtful, however, whether this increase would pay for the extra labour required, and the increased strain upon the cows would most probably cause them to lose condition if the frequent milking were continued for long.

Colostrum Milk. For a few days before and a few days after calving, the cow gives what is known as *colostrum milk*, or *beestings*. Colostrum differs from ordinary milk both in appearance and in composition. It is yellow in colour, and is thick and oily in appearance. The composition of colostrum milk varies considerably, but it is usually poor in lactose and fat, and rich in albumen and ash. The composition of an average sample of colostrum is as follows:

Water	73	per cent.
Fat	3·3	,,
Casein	4·8	,,
Albumen	15	,,
Sugar	2·1	,,
Ash	1·8	,,

When boiled, colostrum milk coagulates, on account of the large amount of albumen which it contains. Albumen generally forms 14 or 15 per cent. of colostrum; in ordinary milk it is present to the extent of only 0·7 per cent.

The young calf should always be allowed to receive the colostrum, because it is very nourishing and also acts as a stimulant to the digestive system.

Colostrum milk is not considered fit for human consumption, and it spoils the quality of dairy products

if used in their manufacture. During the four or five days after calving, it gradually changes to normal milk. When the milk will boil without coagulating, it is fit for ordinary use again.

QUESTIONS ON CHAPTER II.

1. Explain why the temperature of milk affects the lactometer reading. State the rule for correcting the reading when the temperature is above or below 60 degrees Fahr.

2. Why does milk boil more quickly than water? Explain fully.

3. Describe how to detect (*a*) skimmed milk, (*b*) watered milk, (*c*) watered and skimmed milk.

4. What is the normal specific gravity of milk, and why is it so constant?

5. Explain the structure of the Quevenne lactometer.

6. Say what you know about colostrum milk.

CHAPTER III.

BACTERIA IN MILK.

ALL milk, even when freshly drawn from the cow, contains large numbers of very small living organisms known as germs, microbes, or bacteria. They are the smallest living things known, being only about one-thousandth of a millimetre in diameter. Nevertheless, they are of the utmost importance to mankind. Bacteria are responsible for all our typhoid, cholera, tuberculosis, diphtheria, and other epidemics.

The general action of bacteria is to split up organic matter (that is, vegetable and animal products) into simpler substances. Some of these simple substances pass off as gases, which are the cause of bad smells accompanying putrefying matter.

The organisms which make substances "go bad" are known as "putrefactive bacteria."

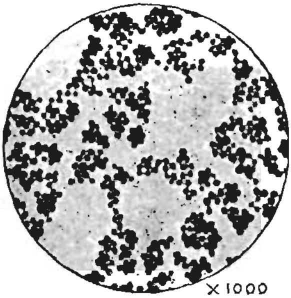
Sometimes their action to a limited extent is desirable, as in the ripening of dairy products and the fermentation of beer and spirits. Bacteria, although only recently understood, have always been of the utmost importance to the dairy industry and to agriculture generally.

Consequently, the dairyman should know something

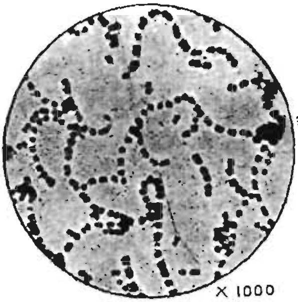
about the ways of controlling these minute organisms, which, although themselves invisible to the naked eye, make their effects everywhere apparent.

Bacteria are properly called "plants," but they bear little resemblance to what is usually understood by the word, being simply very minute one-celled structures.

Kinds of Bacteria. A very common form of bacteria is that known as the "coccus." It is spherical in



(*a*) Micrococci.



(*b*) Streptococci.

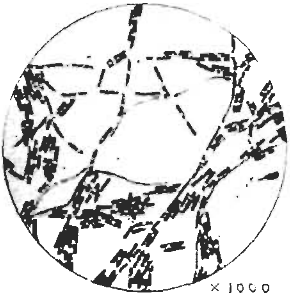
FIG. 8.—MICROCOCCI AND STREPTOCOCCI.

shape, and varies in size from ten-millionths to sixty-millionths of an inch. When they occur in no definite order these germs are known as "micrococci." Frequently, however, they are found in rows or chains, and are then called "streptococci." Bacteria of this class are the cause of mammitis in cattle, ulcers, erysipelas, and abscesses.

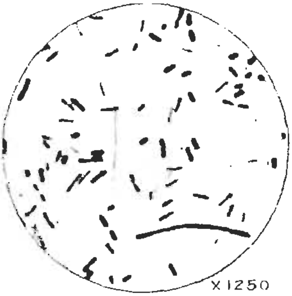
There are two other main types of bacteria, namely, "*bacilli*" and "*spirilla*."

Bacilli (Latin *baculus*, a stick) are more or less rod-shaped, and occur either singly or in chains. Some of

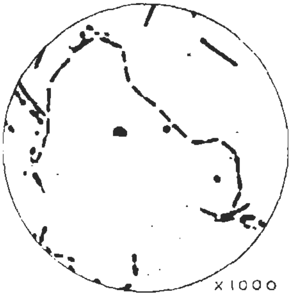
them are provided with small, hair-like structures called "flagella," with which they propel themselves through liquids. Bacilli are responsible for many serious diseases, such as anthrax, lockjaw, leprosy, diphtheria, and tuberculosis.



(*a*) With spores.



(*b*) Showing various forms in one type.



(*c*) Showing sub-divisions.

Fig. 9.—Various Forms of Rod-shaped Bacteria.

Some of them, on the other hand, are very useful, such as the acetic-acid bacillus, which makes vinegar from beer, and the lactic-acid bacillus, which causes the ripening of dairy products. The butyric-acid germ, which causes butter to become rancid, is also rod-shaped.

The third class of bacteria is not so common as the two just described. It consists of germs which are

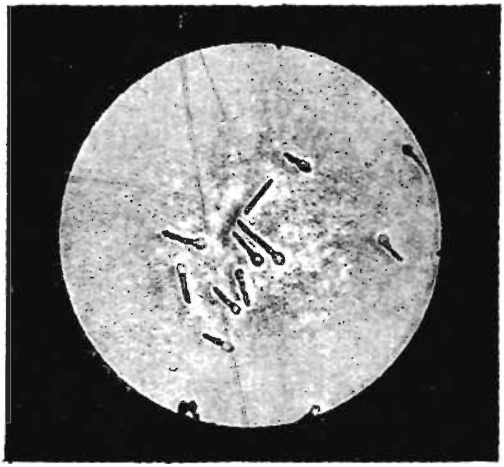


Fig. 10.—Bacteria of Tetanus (Lockjaw). (Magnified 1500 times.)
The rounded bodies at the ends of the bacteria are spores.

spiral in shape and, like the bacilli, may be provided with flagella. Germs of this class are called " spirilla." The cholera microbe is perhaps the most important example.

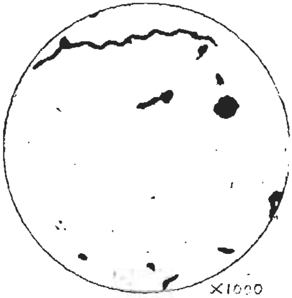


Fig. 11.—Spirilla.

The Growth of Bacteria. Most bacteria multiply very rapidly by a process of division, and so are called " fission " or " splitting " bacteria (Latin *fissum*, a division). The individual divides into two smaller cells; each cell soon becomes full-grown and then divides in

the same manner. Some bacteria divide every half-hour. At this rate one germ would produce about 300,000,000,000 of its kind in two days. This enormous rate of growth, however, is soon checked, because the bacteria produce substances harmful to themselves, and because the supply of food is rapidly exhausted.

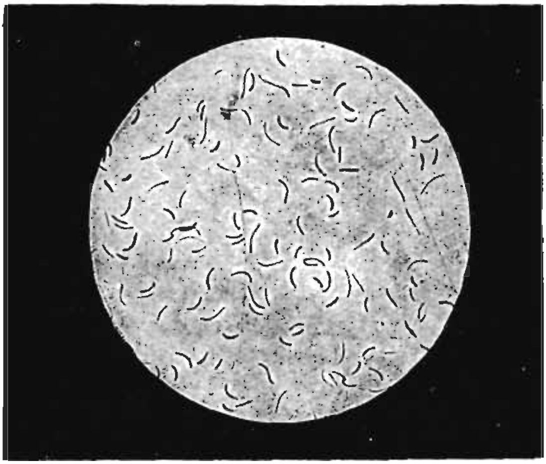


FIG. 12.—BACTERIA OF CHOLERA. (Magnified 1500 times.)

Fungoid Growths. There is also another kind of plant growth found in milk, which is quite different from the bacteria just described and is more highly developed. This is really a fungus, and differs from the fission bacteria in structure, size, and method of reproduction. It consists of a thin, whitish, much-branched stem, which sends out small lateral growths like stalks. These lateral stalks become modified at the tips and produce minute spores or seeds.

Oidium lactis is a fungus plant which frequently

grows in stale starters and in cream ripening for butter-making. From the long branching stems, or *hyphae*, lateral stalks are produced, bearing chains of spores at their ends. These spores are single cells, which germinate under favourable conditions and produce new plants.

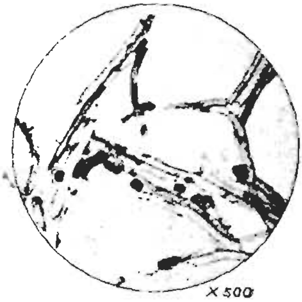


FIG. 13.—OIDIUM LACTIS (Much magnified.)

Round spores are produced at the ends of the branches.

Fungus plants of this description occur in large numbers in bad milk. They make rapid growth, and help on the process of putrefaction. Fully-developed fungi and bacteria can generally be killed by boiling, but the destruction of spores is a much more difficult matter. It is described under "Sterilization" in the next chapter.

The Source of Bacteria. Bacteria are found everywhere in nature, and are present in the freshest and cleanest of milk. In the udder itself there are comparatively few bacteria, but the milk in the teats contains millions which have entered from the air and then multiplied. By taking proper precautions, however, milk can be obtained from the cow almost pure; most of the contamination generally takes place afterwards. Many bacteria enter the milk from the milker's hands and from dirt on the udder. Dust in the air is always laden with germs, many of which enter the milk as it passes from teat to milk-pail. Dirty caps and other dairy utensils form another prolific

source of bacteria. If particles of milk are left adhering to cans, they will soon become breeding-places for millions of bacteria, which will contaminate the next lot of milk. Flies are also a very bad source of contamination. A single fly sometimes carries more than one hundred million germs.

Bacteria in Milk. Some of the bacteria in milk are useful, others are very harmful. Besides disease germs, many other species of undesirable bacteria are

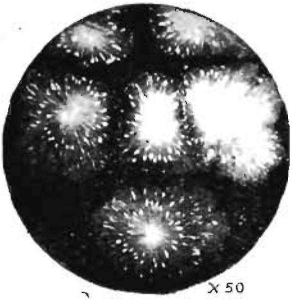


FIG. 14.—A COLONY OF BACTERIA. Grown in gelatine.

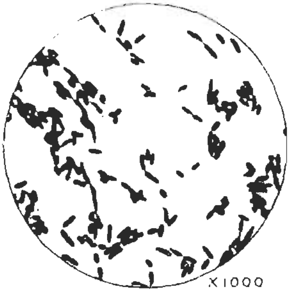


FIG. 15.—BACTERIUM VISCOSUM. The cause of slimy milk.

found in milk. Some impart a bitter flavour to the milk, others a "soapy" taste, and about twenty distinct species have been found which make the milk thick or "ropy." Blue milk, red milk, and yellow milk are also caused by various kinds of bacteria, but they are fortunately not very common.

The useful bacteria are those which produce lactic acid from the milk-sugar. More than a hundred species are thought to possess this power, but there is one much more prominent than any of the others, and to it the name "lactic-acid bacillus" has been given.

The souring of milk and the ripening of cream depend upon the production of lactic acid. Fresh milk ordinarily contains 5 per cent. of milk-sugar, but less than one-fifth of this quantity is acted upon by the bacteria, because too much lactic acid seems to be harmful to them. The maximum acidity of milk is said to be 0·9 per cent.; that is, thoroughly sour milk contains about 0·9 per cent. of lactic acid.

The degrees of sourness required for various purposes are as follows:

0·1 per cent. sour - -	fresh milk.
0·2 ,, ,, - -	limit for pasteurization.
0·3 ,, ,, - -	limit for cheese-making.
0·4 ,, ,, - -	sour to taste and smell.
0·5 ,, ,, - -	slightly thick.
0·6 ,, ,, - -	churning-point.
0·65 ,, ,, - -	limit for churning.
0·7 ,, ,, - -	too sour for churning.
0·9 ,, ,, - -	limit of sourness.

Full directions as to the method of determining the degree of sourness in milk are given in the chapter on the "Acidity of Milk."

Bacteria require Warmth. Lactic-acid bacteria are present in all milk, however pure and fresh it may be. They multiply very rapidly, each germ producing many others by the process of division. The most favourable temperature for this is 98 degrees Fahr. Lower temperatures hinder this growth, and freezing stops it altogether. If milk be cooled to 50 degrees, each germ multiplies to five in 24 hours. At 70 degrees, in the same time, one germ will produce 750 others. This, of course, makes a great difference in the time required for the milk to become sour. At 50 degrees

it requires 200 hours to curdle, but at 70 degrees the rapid increase of bacteria causes it to curdle after standing only 40 hours. One cubic centimetre of curdled milk contains about two and a half billion of these lactic-acid germs. From this it is very evident that, if milk is to be kept sweet, it should be cooled immediately it is drawn from the cow, and should not be allowed to get warmer than 50 degrees Fahr.

This may be done by placing the cans of milk in cold water.

Cleanliness. Bacteria thrive in dirty surroundings. For this reason, great attention should be paid to cleanliness in all things connected with milk. The floor of the milk-shed should be made of concrete, and the walls and woodwork frequently limewashed. The milker's hands should be washed in warm water, and the cow's teats wiped with a damp cloth before milking. All cans, buckets, and other utensils must be rinsed with warm water and scalded after use and frequently cleansed with soda, washing-powder, or lime.

The Fore-milk. The first drawn milk or "fore-milk" always contains more bacteria than the rest. This is because it is contained in the teats where germs can easily enter from the air. Consequently, it becomes contaminated, and the first few squeezes from each teat should always be thrown away. Since the fore-milk contains very little butter-fat, this does not involve any serious loss, even in the case of a big herd; and, if it is remembered that half the bacteria in a milking come from the fore-milk, the advantage of so doing will be quite evident.

Rapid souring or fermentation of milk is a sign that the milk has been contaminated, and is unfit for human consumption.

QUESTIONS ON CHAPTER III.

1. Describe, with examples, the three principal classes of bacteria.

2. From what sources do bacteria enter milk ?

3. Say what you know about lactic acid bacteria.

4. How do bacteria multiply ? What is the effect of temperature upon their multiplication ?

5. What is the fore-milk ? Why should it be rejected ?

6. How do fungoid growths, such as oidium lactis, differ from bacteria ?

CHAPTER IV.

CONTROL OF BACTERIA.

THERE are three main ways of overcoming the action of bacteria :

1. By the use of chemical preservatives.
2. By subjecting the bacteria to very low temperatures (refrigeration), and
3. By heating to a high temperature for a certain period of time (pasteurization and sterilization).

Chemical Preservatives. The easiest way of overcoming bacteria is to use some chemical substance which kills them. The substances which possess this power, however, are also more or less poisonous to human beings, and so they are not suited for general use in preserving dairy products. Formalin and bichromate of potash may be mentioned as examples of such substances ; an account of the common chemical preservatives will be found in Chapter XIV.

Refrigeration. If the temperature falls below a certain point, the growth of bacteria is checked. Consequently, if foods are frozen, they will keep for an indefinite length of time without putrefying. This

is a most important matter, because it enables all kinds of perishable goods to be carried for thousands of miles to the great markets of the world. Modern cargo ships are fitted with freezing-chambers in which meat, butter, and other perishable products are stored during the voyage. For this purpose a temperature considerably below freezing-point must be obtained by some artificial means; the process is known as Refrigeration.

The Principle of Refrigeration. Whenever liquids evaporate, heat is lost. However strongly it is heated, an open vessel of water cannot be made to reach a temperature higher than boiling-point (212 degrees Fahr.). When that temperature has once been reached, any further heating causes the water to become steam. The change of water into steam uses up the heat, and so the temperature of the water cannot rise above boiling-point. The same principle applies to other liquids—evaporation is always accompanied by loss of heat.

Ether, methylated spirits, and benzine evaporate much more rapidly than water. If the hand is moistened with ether, it will soon become dry, and feel very cold on account of the rapid evaporation which has taken place. The same thing can be shown by dipping the bulb of a thermometer into ether and then allowing it to dry; the mercury falls considerably.

The following experiment, which is also quite simple, illustrates the principle of refrigeration very clearly.

Pour a little water on to a flat piece of wood. Then pour some ether into a small beaker, and stand it in the water. Blow vigorously into the beaker with a

bicycle pump or a small pair of bellows, so as to hasten evaporation. The ether will soon all disappear, and the consequent loss of heat will cause the water under the beaker to freeze into a solid piece of ice.

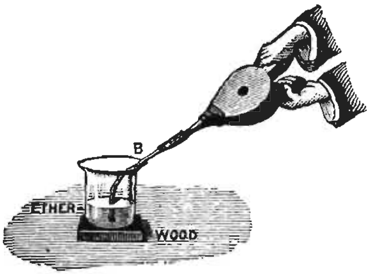


FIG. 16.—HOW TO FREEZE WATER BY THE EVAPORATION OF ETHER.

Ammonia Refrigeration. Ether is not suitable for refrigerating on a large scale; ammonia is the substance generally used. Ammonia is a pungent-smelling gas, formed by the chemical union of nitrogen and hydrogen (NH_3). The common so-called "liquid ammonia" is a solution of this gas in water. It is not really liquid ammonia, any more than brine is liquid salt.

By subjecting ammonia gas to great pressure, however, we can obtain true liquid ammonia; this is liquid ammonia in the sense that water is liquid steam. The liquid ammonia so obtained must be kept in strong steel cylinders; if the pressure is released, it immediately becomes gas again. Ammonia changes from liquid to gaseous form very rapidly indeed, and so causes great loss of heat. For this reason, ammonia is the substance generally used for refrigeration.

The liquid ammonia is allowed to evaporate in a coil of pipes which are placed in the refrigerating-chamber. This brings down the temperature of the chamber to considerably below freezing-point. The walls of the refrigerating-chamber are generally made of two layers of brick, and the space between the layers

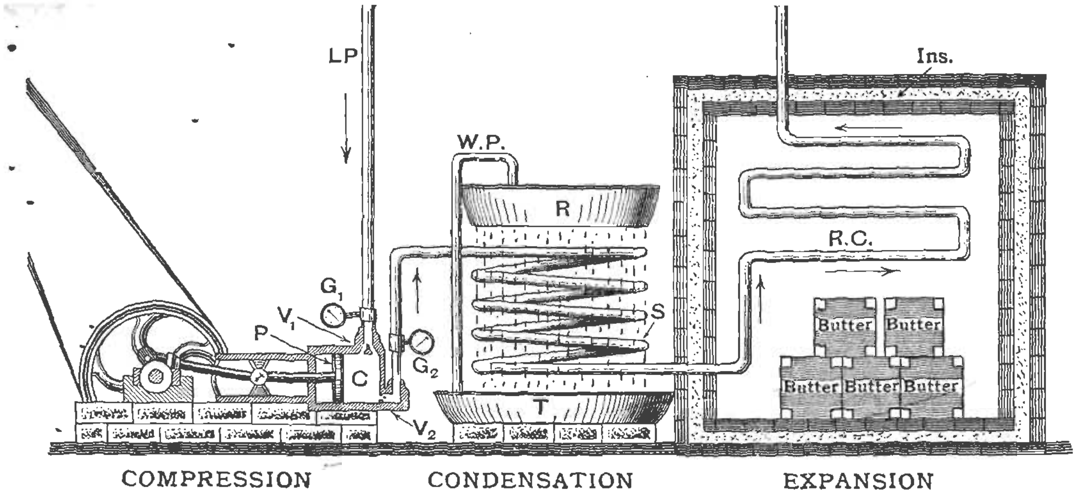


FIG. 17.—AMMONIA REFRIGERATION.

- G_1. Gauge indicating low pressure of the ammonia gas returning to the compressor.
- V_1. A valve which admits the gas into the compressor and prevents it from being driven back again into the low-pressure pipe (LP).
- C. Cylinder in which the gas is compressed by the piston (P).
- V_2. A valve through which the compressed gas leaves the cylinder at a high temperature.
- G_2. Gauge indicating high temperature of gas leaving the compressor.
- S. Condensing coil, in which the heated and highly compressed gas is cooled by water falling from the reservoir (R): this causes the ammonia to change from gaseous to liquid form.
- W.P. Water-pipe conveying water to the reservoir. T. Tank for catching the water which falls from the condensing coil.
- R.C. Refrigerating coil in the freezing-chamber. In these pipes the ammonia becomes gas again, causing a very low temperature.
- Ins. Insulating material (cork, silicate cotton, or pumice) between two layers of brick.

is filled with some material which is a bad conductor of heat; this insulates the chamber and prevents heat from entering it through the walls. The ammonia which has evaporated in the coil of pipes within the freezing-chamber is forced along to a machine which compresses it into liquid form again. The ammonia is made intensely hot by the compression, and the great heat at first prevents it from assuming the liquid form. It is then passed through a coil of cooling pipes, over which cold water is kept running. This takes the heat from the compressed gas, which then forms liquid ammonia. The liquid ammonia is passed through pipes into the refrigerating-chamber, where it is allowed to become vapour again, and the process is repeated.

There are thus three stages in ammonia refrigeration:

1. *Compression* of the gas.
2. *Condensation* of the hot compressed gas into liquid ammonia.
3. *Evaporation* of the liquid ammonia in the refrigerating-chamber.

Pasteurization and Sterilization. Freezing checks the action of bacteria and prevents their multiplication, but does not actually kill them. They lie dormant, but quickly revive if warmth is restored; in a similar manner frogs sleep during the cold of winter, but awaken to life when spring comes. Since refrigeration merely causes the bacteria to remain dormant, it does not possess the power of making contaminated milk wholesome. If milk has become contaminated by the entry of germs of putrefaction or disease, there is

only one way of making it wholesome again, and that is to destroy the germs by strongly heating. For so long as it lasts, refrigeration prevents bacteria from multiplying and causing decay, but the application of strong heat destroys them altogether.

Pasteurization. The commonest means of rendering milk free from harmful bacteria is pasteurization. The process derives its name from M. Louis Pasteur, the noted French bacteriologist, by whom it was invented.

Pasteurization consists of heating the milk, keeping it for a certain time at a certain temperature, and then suddenly cooling it. This does not completely destroy all living organisms in the milk, but is sufficient to kill the dangerous disease-bacteria, especially the tubercle bacilli. In Denmark, all skim-milk returned from creameries must be pasteurized. This ensures that the young stock are not fed on germ-laden skim-milk, and the result is that tuberculosis is now rare. In other countries pasteurization is rapidly gaining ground, and although there is still much prejudice against it, its many advantages cannot fail to bring about its adoption sooner or later.

The length of time during which the milk should be heated depends upon the temperature used. The general rule is to heat for 10 minutes at 167 degrees Fahr., for 15 minutes at 160 degrees, or for 30 minutes at 150 degrees. In each case the milk should then be cooled as quickly as possible to 50 degrees. In order to save time, milk is often heated to 185 or 190 degrees and then cooled immediately. This requires to be carefully done, or it may impart a burnt flavour to the

milk. According to the latest reports, recent experiments have shown that the best results are obtained by heating the milk at 140 *degrees for* 20 *minutes*.

Rapid Cooling. Rapid cooling is an essential part of pasteurization, for three reasons:

(1) It eliminates from the milk any "cooked" flavour which may have been caused by the heating. The main objection to the use of a high pasteurizing temperature is that it is likely to cause a "cooked" taste. Rapid cooling, however, overcomes this and so enables us to use a high pasteurizing temperature, thus saving time and also ensuring a more complete destruction of germs.

(2) The *sudden change* of temperature helps to destroy the germs.

(3) If the milk cools slowly, and remains for a considerable length of time between 80 and 100 degrees Fahr., the gentle warmth will cause many undestroyed spores to develop and spoil the good effect of the heating. The importance of sudden cooling is shown by the results of the following simple experiment.

A sample of fresh milk was divided into three portions, A, B, and C. The portion A received no treatment whatever, but was kept as a control to show the effect of pasteurization on the other two. B was pasteurized properly, being heated for 10 minutes at 167 degrees and then *suddenly cooled* to 50 degrees. The portion C was heated in the same way, but allowed to *cool gradually*. The three samples were then allowed to stand for a week, during cold weather. At the end of that time they were examined and tested for acidity. The results are given in the table below. They show

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the value of pasteurization and, at the same time, the *importance of sudden cooling.*

Sample.	Treatment.	Acidity.	Condition.
A	None - - - -	0·75%	Very sour to taste and smell : curdled.
B	Heated for 10 minutes at 167 degrees Fahr., and cooled *suddenly*	0·2%	Slightly sour.
C	Heated for 10 minutes at 167 degrees Fahr., and cooled *gradually*	0·38%	Unpleasant "bad" smell.

Milk which contains more than 0·2 per cent. of lactic acid is too sour for pasteurization ; the heating would curdle it.

Experiment. For the purpose of performing experiments on a small scale, milk may be pasteurized in the following way. Obtain two glass beakers, a large test-tube, a thermometer, a watch, a Bunsen burner or a spirit-lamp, and a supply of cold water. Partly fill the beaker with water and place it over the Bunsen burner. Pour some milk into the test-tube, and stand it in the beaker of water. Insert the thermometer into

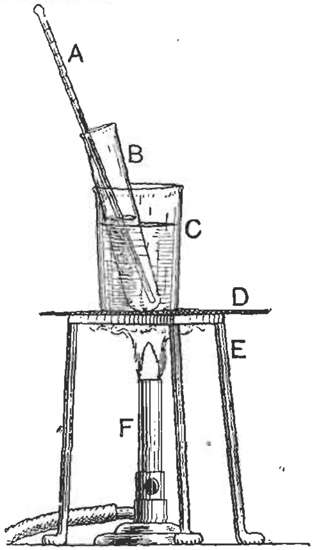

FIG. 18.—APPARATUS FOR SMALL PASTEURIZING EXPERIMENTS.
A. Thermometer. B. Test-tube of milk. C. Beaker of water. D. Wire gauze. E. Iron stand. F. Bunsen burner.

the test-tube, so that the temperature of the milk may be ascertained from time to time. Light the gas and heat the beaker until the milk reaches the desired temperature. Maintain this temperature, by regulating the size of the flame, for the required length of time.

After the heating has been completed, cool the milk suddenly by placing the test-tube in a beaker of the coldest water obtainable ; the water should be renewed as soon as it loses its chill. If a beaker and a test-tube are not at hand, the milk may be pasteurized by heating it in a clean cup over a kettle of water.

Pasteurization and Disease Germs. On account of its nutritive qualities, milk is an ideal home for germs, and so it is not surprising that many diseases are spread by impure milk.

It is well known that many cases of tuberculosis and typhoid fever are traceable to the milk-supply. Disease germs in milk are easily killed by pasteurization. Five minutes' heating at 160 degrees Fahr. is sufficient to kill the germs of typhoid, scarlet fever, and diphtheria. Tubercle bacilli are killed by 10 minutes' heating at the same temperature.

Pasteurized milk is said to be just as digestible and just as nourishing as raw milk.

Summary.—Advantages of Pasteurization. The advantages of pasteurization may be summarized as follows :

1. The destruction of disease germs makes milk safe for human consumption.
2. The feeding of pasteurized skim-milk to young stock helps to prevent the spread of tuberculosis and other cattle diseases.

3. Pasteurizing milk makes it keep sweet longer in hot weather, because the lactic acid germs are destroyed.
4. By pasteurizing his cream, the butter-maker obtains greater control over the process of ripening.
5. Pasteurized-cream butter has been found to be more reliable than that made from ordinary cream, and generally to be free from those unpleasant taints which the latter often possesses.

Sterilization. Sterilization means the complete destruction of all living organisms.

For ordinary purposes it is quite sufficient to pasteurize milk, but pasteurization leaves undestroyed a large number of minute spores. Within a few days these spores develop into harmful bacteria and fungoid growths, which cause the milk to putrefy. The killing of these undeveloped spores is a difficult matter, but once it has been effected, the milk will keep quite good for an indefinite length of time, provided that no fresh germs are allowed to enter it.

The total destruction of all living organisms in milk is known as sterilization. There are two methods by means of which milk can be sterilized.

I. **Immediate Sterilization.** The first method is really a severe form of pasteurization. It consists of keeping the milk at a high temperature (250 degrees Fahr.) for two hours. This is considerably above boiling-point, and in order to reach it, the milk must be heated under pressure in a closed vessel.

Generally the milk is put into small bottles, which are then sealed and placed in the sterilizer. This is a very strong oven, perfectly air-tight, and capable of resisting a certain amount of pressure. When heat is applied, the increased pressure of the air within the sterilizer prevents the milk from boiling until a higher temperature than the ordinary boiling-point is reached. The temperature usually chosen is 250 degrees Fahr., maintained for two hours.

II. **Slow Sterilization.** The second method is slower, but does not require a special sterilizing oven. It consists of encouraging the spores to germinate, and then killing them by heating to pasteurizing temperature.

First of all the milk is subjected to a temperature of 165 degrees for two hours; this destroys all living organisms except undeveloped spores. Then it is allowed to cool to 100 degrees Fahr., and kept at that temperature for two or three days; this causes most of the spores to grow. The milk is then pasteurized again in order to destroy the new growths. This is repeated several times, until no undestroyed spores are left.

The former method is, of course, much quicker, but it gives the milk a dark colour and a "cooked" taste; the second method is very slow, but it produces neither of these defects in the milk.

If milk is properly sterilized and sealed to prevent subsequent contamination, it will keep for an indefinite length of time.

QUESTIONS ON CHAPTER IV.

1. What is pasteurization? Why is rapid cooling important?

2. How may milk be sterilized without the use of special apparatus?

3. What are the advantages derived from pasteurization?

4. Give an account of ammonia refrigeration.

5. How would you pasteurize a quart of milk with ordinary kitchen utensils?

CHAPTER V.

METHODS OF CREAM SEPARATION.

Cream. The chief difference between milk and cream is the fact that cream contains a higher percentage of butter-fat than is found in milk. The percentage may vary from about 15 per cent. to 50 per cent., or more, of the cream. In many countries the law demands that all cream offered for sale shall contain not less than a certain percentage of butter-fat, generally 18 to 20 per cent. A cream which contains over 35 per cent. of fat would be classed as thick cream, one with less than 20 per cent. as thin, and one containing between 20 and 35 per cent. as a medium cream. There is no fixed standard, and sometimes what is sold as cream is so poor that it can hardly be distinguished from milk. Owing to its high fat-content, cream is more yellow than milk, and has a lower specific gravity. The weight of a given quantity of cream varies, however, according to the percentage of fat which it contains. The following table shows the weight of a quart of cream of different percentages of fat.

Percentage of Fat.	Weight of one quart of Cream.
20	2·439 lb.
25	2·420 ,,
30	2·408 ,,
40	2·379 ,,
50	2·339 ,,

A quart of ordinary milk weighs 2·58 pounds. The fat-globules in cream are larger than the average globules found in milk, and the smallest of all are seen in skim-milk. This is because the large globules are more easily separated from the milk-serum than small ones. Whether the cream is obtained by the separator or by pan-setting, it always contains the large globules, the smaller ones being left behind in the skim-milk. Cream is composed of exactly the same substances as milk, but in different proportions.

Average cream contains :

Water - - -	65·4	per cent.
Butter-fat - - -	26·0	,,
Casein - - -	3·0	,,
Albumen - - -	0·8	,,
Milk-sugar - - -	4·2	,,
Ash - - - -	0·6	,,

Separation of Cream. The separator is now almost universally used for getting cream from milk, and its many advantages make it by far the best method to employ.

The old methods of creaming all involve a considerable loss of butter-fat, but a good separator leaves very little fat in the skim-milk. The fat thus saved very soon pays for the separator. Some of the ways of cream-raising employed before the coming of the separator are briefly described below. They all depend upon the force of gravity. Milk-serum has a higher specific gravity than butter-fat ; that is, it is heavier, bulk for bulk. This causes it to sink to the bottom and to force the fat-globules to the top. Owing to the stickiness of the milk-serum and the small amount of

difference between the specific gravity of milk-serum and that of butter-fat, this separation is very slow. Under ordinary conditions, it requires about twenty-four hours, but even then it is not complete. Certain improvements on the ordinary pan-setting aim at hastening creaming by overcoming the stickiness of the milk-serum or by increasing the difference between the specific gravity of the fat-globules and that of the serum.

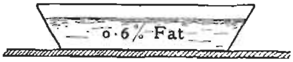

Fig. 19.—Shallow Pan-setting. Average loss, about 0.6 per cent. fat.

The following are some of the old-fashioned methods of cream-raising which are now being rapidly superseded by the separator.

1. **Shallow Pan-Setting** This is the commonest of the old-fashioned methods of creaming milk. The milk is set in shallow pans about 4 inches deep, and allowed to stand at 60 degrees Fahr. for at least twenty-four hours. At the end of that time the cream is skimmed off. Under the most favourable conditions about 0·5 per cent. of fat is left in the skim-milk by this method, and in some cases the loss may exceed 1 per cent.

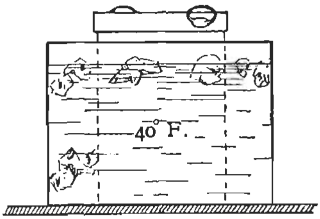

Fig. 20.—Deep Pan-setting. Milk kept at 40° F. in a tank of iced water. Average loss, about 0.25 per cent. fat.

2. **Deep Pan-Setting.** For this system of creaming, pans about 20 inches deep are required. They are filled with milk and placed in ice-cold water so as to bring the temperature of the milk down to 40 or

45 degrees Fahr. This method is more economical than shallow pan-setting, and also more rapid, but the milk should be allowed to stand for twenty-four hours if possible. The loss of fat in the skim-milk is generally about 0·2 or 0·3 per cent.

3. **Cream Raising by Diluting.** If diluted with either hot or cold water, milk gives a larger amount of cream than by either of the foregoing methods, but the cream is generally poor in butter-fat. The purpose of adding the water is to lessen the viscosity of the milk-serum and so permit the fat globules to rise more easily. As a rule, the warm milk is diluted with an equal quantity of water at 100 degrees Fahr., well mixed, *and allowed to stand for twelve hours. This is the* most wasteful of all the creaming methods. The loss of fat is generally above 0·7 per cent. Another objection to the water-dilution process is that the skim-milk is made very thin, and its value for feeding purposes is thereby diminished.

4. **Cream Raising by Scalding.** This method is especially suitable for hot climates where milk readily turns sour. The milk is usually put into a deep pan and placed upon a stove ; a steady heat is applied, and the fat rises rapidly. At the same time, the milk is "pasteurized" by the heating, and so is prevented from souring for a considerable time. The milk must be scalded when quite fresh or the heat will cause it to curdle.

5. **The Jersey Creamer.** This method is not very commonly employed, but is described here because it depends upon a very important principle. The "creamer" consists of a pan having double sides and

bottom. It is filled with milk, and then hot water is poured in to fill up the space between the double sides. *When the milk reaches a temperature of 110 degrees Fahr.*, the hot water is drawn out, and ice-cold water is run through to bring the temperature of the milk down to about 50 degrees Fahr. The skim-milk is then allowed to run out through a tap, leaving the cream behind. By this method the cream can be obtained very rapidly. Heating the milk lowers its specific gravity. When the cold water is put in, the milk-serum loses its heat much more quickly than the butter-fat does. The effect of this is to increase the difference between the specific gravity of the serum and that of the fat-globules; the globules are thus enabled to rise more readily.

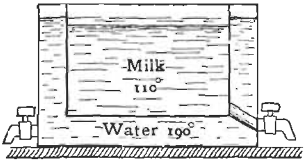

FIG. 21.—THE JERSEY CREAMER.

6. **The Cream Separator.** The separator differs from the foregoing methods in a very important manner. Its working depends not upon gravitation, but upon the principle of centrifugal force; this will be fully described in the next chapter. The "centrifugal method," as it is called, has many advantages over the old gravity systems of creaming.

Advantages of the Separator. 1. The loss of butter-fat in separator skim-milk is very small. When properly worked, a good hand separator should not lose more than 0·03 or 0·04 per cent. fat. The economy of the separator is shown by the following example: Suppose the losses of butter-fat by separator and shallow pan-setting to be 0·03 and 0·6 per cent., respectively;

that means that the gain in fat achieved by using a separator is equal to 0·57 per cent. of skim-milk by weight. An average cow produces 7000 pounds of milk in a year; this should yield about 6000 pounds of skim-milk. The weight of butter-fat saved per cow in a year will therefore be 0·57 per cent. of 6000 lb. = 34·2 lb. With butter-fat at a shilling per pound, this represents a saving of £1 14s. 2½d.; if there are twenty cows in the herd, the total saving will be £34 4s. 2d. The cost of the separator would not exceed £15. There are few dairy-farmers nowadays who have not invested in one of these machines, which pay for themselves and yield a handsome profit in a single year.

2. By means of the separator it is possible to obtain cream immediately after milking. As a matter of fact, it is best to separate the milk before it becomes cold.

3. The thickness of the cream can be regulated exactly. Most authorities agree that a 40 or 45 per cent. cream is best for butter-making. By the gravity processes it is difficult to obtain cream testing over 30 per cent. fat, but any particular quality of cream can be obtained from the separator by simply turning a screw.

4. The separator is a much more convenient method. Not nearly so many appliances or so much room and time are required as for the old systems of pan-setting.

5. The skim-milk and cream are obtained perfectly sweet, and their degree of acidity is so low that they can be pasteurized without risk of curdling. In hot weather milk set in pans often curdles before it can be skimmed.

6. The separator method is the most sanitary. Open pans of milk readily absorb bad odours and become contaminated by bacteria from the air.

7. The labour involved by the use of a separator is small when compared with the troublesome process of setting the milk in the pans, protecting it from contamination, skimming the cream off, and keeping the pans perfectly clean.

QUESTIONS ON CHAPTER V.

1. What weight of butter-fat would be lost in creaming 800 lb. of milk, (*a*) by water dilution, (*b*) by deep pan-setting, (*c*) by shallow pan-setting, (*d*) by the separator ?

2. Explain, with an example, how the separator pays for itself.

3. Compare deep pan-setting with shallow pan-setting.

4. Write a note upon the composition of cream. Explain why the weight of cream varies.

5. In the gravity systems of creaming, what causes the cream to separate from the milk ? What tends to prevent separation, and what means can be taken to aid separation ?

6. Enumerate the advantages of the separator over the old-fashioned methods of creaming.

CHAPTER VI.

THE SEPARATOR.

Centrifugal Force. If an object is securely fastened to the circumference of a wheel, and the wheel is made to revolve, the object must necessarily acquire the velocity of the wheel and move round with it. Some fastening is necessary, however, to hold the object to the wheel, for it would otherwise fly off upon a straight path: to make the object move in a curved line, as it does when fastened to the wheel, force must be exerted by the fastening.

If, while the wheel is rotating, that fastening is suddenly released, the object will immediately leave the curved path and continue its motion in a straight line, the new direction being that of a tangent to the circumference of the wheel at the point where the fastening was released. In other words, any object which is whirled around the circumference of a circle acquires a tendency to leave the wheel and follow a straight path forward, in the direction of the rotation, and outwards from the wheel.

This new path is a tangent to the circle: it can be drawn by making a line just touching the circumference at right angles to the radius drawn to the point of

contact. Riding a bicycle without mud-guards in wet weather affords an excellent example. The particles of mud do not remain on the tyre, neither do they fly straight out from the axle, but are thrown forward upon the rider's back.

Rapid rotation, then, gives objects a forward-and-outward tendency: the greater the speed of rotation, the greater will be the force required to prevent them from flying off at a tangent. This outward tendency is called Centrifugal Force.

It can be well illustrated by the following simple experiment.

Take a piece of cardboard, and make a small hole through the middle. Then hold the cardboard in a horizontal position by means of a pin through the hole, and give it a sharp tap to make it spin round quickly. While the cardboard is spinning, drop a small object, such as a piece of chalk, upon it; note that the object is immediately thrown off the cardboard.

This is a most important principle which is made use of in various manufactures. For example, wool is dried by being revolved in a drum with perforated sides. The centrifugal force developed drives the water from the wool through the sides of the drum. The same principle is of immense importance to modern dairying, as both the separator and the Babcock test depend upon it. If the milk is placed in a vessel and whirled round rapidly, its particles tend to fly out at a tangent: the more rapid the whirling, the stronger the tendency. This causes a separation of cream from milk, because the milk-serum, being heavier than the

fat-globules, forces its way to the outside and pushes the globules in towards the centre.

That is why we are able to obtain cream so quickly with the separator, and to get a distinct layer of fat by a few minutes' whirling in the Babcock test. The *application of the principle of centrifugal force has had* a very great influence upon the dairying industry during recent years.

The Separator. The essential part of a separator is the apparatus which takes the cream from the milk. Various devices are employed for this purpose, such as skimming-discs, hoods, screens, perforated cylinders, etc.

The most common device is a series of inverted funnels, or conical discs; that is the system here described and illustrated.

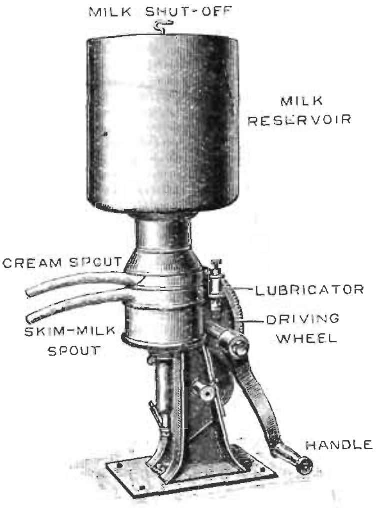

FIG. 22.—A HAND SEPARATOR.

Other makes of separators vary from this, of course, but they all aim at separating cream from milk by means of centrifugal force. They differ chiefly in the methods of admitting the milk, skimming it, and retaining it just long enough for complete skimming. Before studying the internal workings of a separator, we shall just note the following parts, which, although

they do not perform the actual separation, are necessary parts of every separator.

1. **The Stand.** This forms the lower part of the separator. It is heavy, and has screw-holes in the bottom, by which the machine can be securely fastened down.

The purposes of the stand are: to steady the separator, to facilitate the turning of the driving wheel,

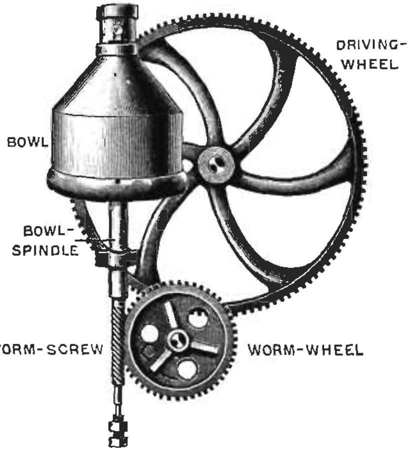

FIG. 23.—DRIVING-GEAR OF A HAND SEPARATOR.

and, as a rule, to contain the mechanism which causes the skimming apparatus to revolve. The structure varies greatly, not only with different makes of separators, but with the different patterns of the same make.

2. **The Driving-Gear.** In hand separators, the driving-gear generally consists of a large cogwheel turned by a handle. By some mechanical device, the power is transferred from this to the bowl-spindle, on

top of which is the bowl containing the skimming-discs. The cogs on the two wheels and the worm-thread on the bowl-spindle are so arranged that one revolution of the driving-wheel will cause a great many revolutions of the bowl, sometimes more than 200. If the driving-gear is to work properly, it must be kept well oiled and in perfect trim. Any part which becomes worn should be renewed at once, or it will prevent smooth and easy working, and also lead to the wearing away of other parts.

3. **The Milk Tank.** This is a round metal tank fixed on top of the separator. In ordinary hand separators, the tank is large, so that a large amount of milk can be poured in at one time. In the case of factory machines, however, the tank is generally small, because the milk is supplied through a pipe in a continuous stream, just sufficient for the capacity of the separator. The bottom of the tank slopes downwards towards the centre, where there is a small hole. Through this the milk runs into the skimming-discs. A long-handled stopper, the *milk shut-off*, fits into the opening, and is used to shut off the flow of milk when necessary.

4. **The Cream Pan.** This fits on the separator below the milk tank. Its purpose is to receive and deliver the separated cream. When the cream leaves the bowl of the separator, it enters the cream pan through an opening in the centre, and then runs through a spout into some vessel placed to receive it.

5. **The Skim-Milk Pan.** The skim-milk pan is similar to the cream pan in shape, but is slightly larger. It is fixed just below the cream pan. As in the case of cream, the skim-milk runs up into the pan through an

opening into the centre, and is then delivered through a spout.

How Cream is separated. The actual process of cream separation goes on within the bowl. This is constructed of strongest steel, and its shape is cylindrical below, conical above, so as to fit the skimming-discs which it contains. The bowl is protected by the outside framework of the separator. The discs are arranged one above the other, like a series of inverted funnels, as can be seen in the diagram of a section of the bowl (Fig. 25).

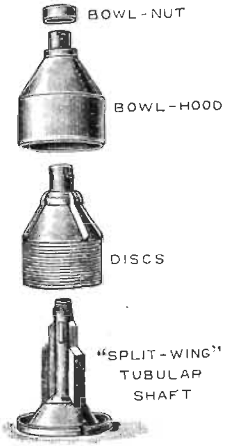

FIG. 24.—THE PARTS OF A SEPARATOR BOWL ("Alfa-Laval" Type).

When the handle of the separator is turned, the upright bowl-spindle revolves rapidly, whirling round with it the bowl of discs which rests on top of it. At the same time milk is allowed to run down from the milk tank into the centre of the bowl, from which it is distributed to the skimming-discs through vertical slits (*B*) in the three wings or buttresses (*C*) projecting from the hollow shaft (*D*). When the milk enters the numerous skimming-discs (*EE*), separation takes place immediately, for the whirling at a speed of several miles per minute gives the milk a terrific outward tendency. This is partially checked by the inclined discs, until the heavier milk-serum has time to separate from the fat-globules and then rush downwards and outwards to the circumference of the bowl (*F*). More

skim-milk follows, and forces it upwards through openings (*H*) at the top of the bowl into the skim-milk pan (*G*).

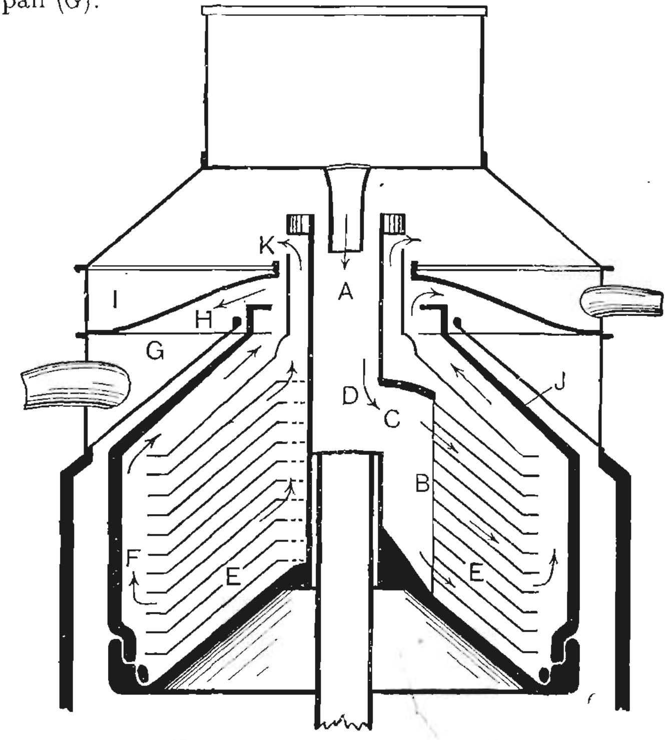

FIG. 25.—SECTION OF THE UPPER PORTION OF A SEPARATOR.

A. Milk inflow. B. Opening in projecting wing.
C. Projecting wing. D. Hollow shaft.
E. Skimming-discs. F. Circumference of bowl.
G. Skim-milk pan. H. Inlet to skim-milk pan.
I. Cream pan. J. Bowl-hood.
K. Inlet to cream pan.

Meanwhile, the globules, together with a small proportion of milk-serum, are pushed inwards and upwards, and so find their way through small openings

into the cream pan (*I*). The zone of separation is about one-third of the way down the discs. The skim-milk occupies the outer two-thirds, and the separated cream is found near the centre, between the three projecting wings (see Fig. 26).

In separating, it is most important that proper balance between the amount of centrifugal force and

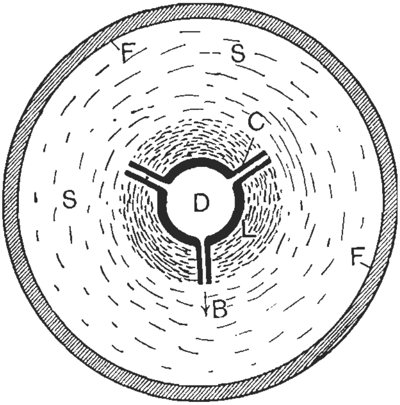

FIG. 26.—DIAGRAM OF A SEPARATOR BOWL, SHOWING WHERE SEPARATION TAKES PLACE.

L. Cream zone between projecting wings. S. Skim-milk zone.
B, C, D, F, as in Fig. 25.

the inclination of the discs should be maintained. If it were not for the discs, the milk would be immediately dashed against the sides of the bowl; their purpose is to hold the milk just long enough for thorough separation to take place, and consequently they are made conical in shape. Since the discs are fixed, the only way in which the proper balance mentioned above can be preserved is by keeping the separator at the proper speed, which is generally marked on the machine.

The speed is not to be varied at will, because the discs are sloped to balance a certain velocity, and, unless this is maintained, the separator cannot be expected to do its work efficiently. An eleven-inch bowl, turning at the rate of 7000 revolutions per minute, carries the skim-milk round at the speed of four miles per minute. In consequence of this great velocity, the sides of the separator bowl suffer a pressure of from ten to fifteen tons per square inch. Greater velocity would throw the cream out with the skim-milk and perhaps break the bowl. Less velocity would develop an insufficient amount of centrifugal force, and so give thin cream.

It is most important to remember that the slope of the discs and other details are made to balance a certain velocity, and consequently this velocity must be strictly maintained.

Working the Separator. In separating, the aim is to get cream of the desired thickness with the loss of the least possible quantity of butter-fat and the expenditure of the minimum amount of energy. In order to obtain this result, many things must be attended to. The main points which have to be taken into account by the dairyman are: (1) the condition of the milk, (2) the working of the separator, and (3) the thickness of cream desired.

Condition of the Milk. Milk should be separated as soon as it is drawn from the cow. This is because of two reasons: (1) The milk is then at the proper temperature, and (2) if allowed to stand for a time, it becomes more viscous or sticky, owing to the action of bacteria and the falling of the temperature, thus

making it more difficult to separate the fat-globules from the milk-serum.

If milk has been allowed to cool, it must be heated again before separating, in order to overcome its viscosity. The temperature usually employed for separating is 90 degrees Fahr. During the winter months it is generally raised to 100 degrees. This is because the cows are then near the end of their period of lactation ; consequently, the milk is thicker than it was during the summer, and the fat-globules are much smaller and more difficult to separate. The separating temperature should never be below 90 degrees Fahr. Higher temperature would make the work of separation still easier, but on account of other considerations it is not advisable to heat above 100 degrees.

The Separator. If a separator is to do its work properly, it must run smoothly, without vibration and without jarring. Owing to the high speed required, the separator is a very delicate machine, and must be carefully handled. What are apparently small details in the working make a considerable difference to the skimming. First of all, the machine should be set perfectly level upon a firm and solid foundation of concrete. Hand separators (of the smallest size) may be screwed down to a firm table, but for the larger machines a properly-made base is absolutely necessary. Belts, bearings, and all other fittings must be kept in the very best repair, because, it should be remembered, a defect in any part will not only cause unsatisfactory separation, but, unless remedied at once, may lead to the wearing away of other parts. The separator is made to run at a certain speed, marked on it by the

makers. This speed should be carefully maintained throughout, and not varied by the operator.

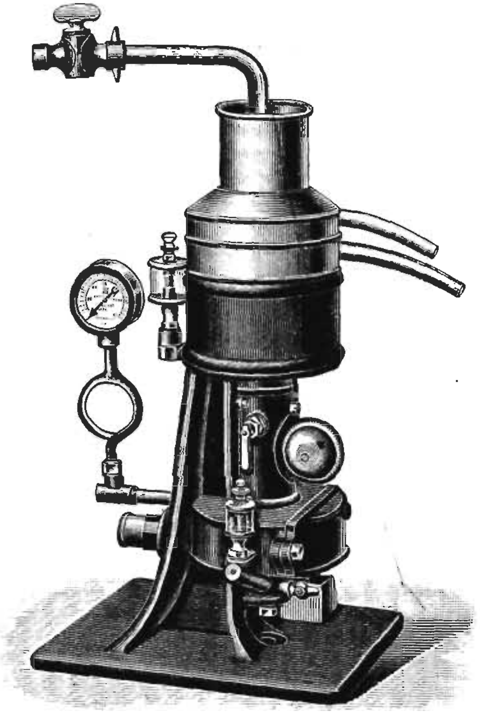

FIG. 27.—STEAM-POWER SEPARATOR.

The machine must always be kept well oiled, and the directions given by the manufacturers for fixing, working, and cleaning it should be carefully followed.

Regulating the Cream. The separator is fitted with a cream-adjusting screw, which is used for regulating the thickness of the cream. It is generally fixed near

the cream-outlet, and a very slight amount of turning (one-eighth of a turn) makes a noticeable difference in the cream. The thickness of cream depends upon the percentage of butter-fat it contains. For butter-making, thick cream is better than thin for several reasons :

(1) It contains a smaller percentage of milk-serum and so is less liable to develop disagreeable taints during the process of ripening.

(2) Owing to the fat-globules being closer together, they do not require so much churning to make them adhere to one another, and so butter is obtained more readily. The cream can be churned at a lower temperature, and a better quality of butter is the result.

(3) There is more skim-milk obtained by having thick cream.

(4) There is not so much cream to be handled in cooling, ripening, and churning ; it will churn more easily, and the quality of the butter will be better. Thick cream means a great saving in time, space, apparatus, and labour.

Cream containing about 45 per cent. of butter-fat is generally considered the best for butter-making. Such cream would be from 10 to 12 per cent. of the whole milk, and 10 pounds of it should make from $4\frac{1}{2}$ to 5 pounds of butter. The percentage of fat in cream can be ascertained exactly by using the Babcock test, but for a rough calculation the following method is much simpler and quicker :

Take a quart measure and a graduated flask ; then place them simultaneously under the two delivery spouts, the quart measure under the skim-milk and the

graduated flask under the cream spout. As soon as the quart measure is full, take them both away, and read how much cream there is in the flask ; we may suppose, for the sake of an example, that there are 5 ounces. The quart of skim-milk contains 42 ounces, making a total of 47 ounces altogether, which represents the quantity of the whole milk. Of this, cream forms $\frac{5}{47}$, or approximately $10\frac{2}{3}$ per cent. If the given sample of milk tests 4 per cent. butter-fat, then the 47 ounces of whole milk must have contained $\frac{47}{100} \times \frac{4}{1} = 1{\cdot}88$ ounces of fat. This is now all in the cream, and so will form $\frac{1{\cdot}88}{5}$ of it ; that is, the cream contains $\frac{1{\cdot}88}{5} \times \frac{100}{1}$ $= 37{\cdot}6$ per cent. of butter-fat.

Cleaning the Separator. As soon as all the milk has been separated, a quantity of warm water should be run through the machine ; this removes dirt and prevents milk from sticking to the discs.

The separator must then be taken to pieces and cleaned. The discs are taken out by means of the disc-holder, and allowed to stand in hot water containing soda. Occasionally they will need a more thorough cleaning, and each disc should then be well rubbed with a brush. Care is necessary in handling the discs, as they are easily bent, and bad skimming is the result of bent discs. Meanwhile the other parts of the bowl, the two pans, and the milk tank can be washed in soda solution and made clean by rubbing with a brush, which is generally supplied with the machine. Finally, all the parts are placed for a minute or two in pure boiling water. They should then be taken out and

set upon a clean bench in the sun to dry, the discs being left on the disc-holder. It is not necessary to wipe them with a cloth; the hot water will very soon evaporate and leave the articles perfectly dry. As a rule, it is much better not to use cloths, even for

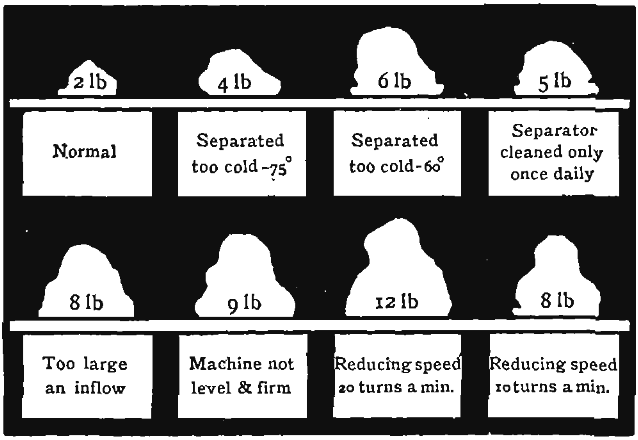

FIG. 28.—HOW FAT IS LOST IN SEPARATING.

The above diagram shows the amount of fat lost in the skim-milk from the milk of one cow in a year. When proper care is taken the loss is about 2 lb.: faulty methods cause much greater losses.

washing. They very easily become contaminated, and dirty cloths will probably do more harm than good. For washing with hot or boiling water, a long-handled brush is much more convenient than a cloth, and it is more easily cleaned and dried.

QUESTIONS ON CHAPTER VI.

1. What is centrifugal force? Explain how it is employed in the separator.

2. What are the principal rules for working a separator?

3. Describe, and illustrate by a diagram, the internal structure of a separator.

4. Why is thick cream better than thin ?

5. 300 lb. of milk, containing 4·5 per cent. fat, are delivered from the separator as 30 lb. of cream and 270 lb. of skim-milk. Calculate the percentage of fat in the cream, neglecting the fat lost in the skim-milk.

6. It is desired to obtain a 45 per cent. cream from 4·8 per cent. milk. If 100 lb. of cream are obtained, calculate the weight of the skim-milk. (Neglect the fat lost in skimming.)

CHAPTER VII.

TESTING FOR FAT-CONTENT.

The Babcock Test.

We have seen how the use of the separator enables us to obtain the butter-fat from the milk in the form of cream, but, although this cream consists very largely of butter-fat, it always contains a big proportion of the other milk-solids and water. In 1890 S. M. Babcock, of the Wisconsin Agricultural Experiment Station, U.S.A., invented a test by which we are able to separate the fat entirely, and so find the exact amount present in milk, cream, cheese, or any other milk-product.

Principles of the Babcock Test. The Babcock test depends upon two things, viz. centrifugal force and the action of sulphuric acid on milk.

The former is easily the more important, but requires the assistance of the acid to make its action complete. The samples of milk to be tested are first poured into small narrow-necked bottles, a quantity of sulphuric acid is added, and the bottles are then whirled rapidly for several minutes. As in the case of the separator, this whirling causes a separation of fat from the milk-serum, the latter displacing the lighter butter-fat

and forcing it in towards the centre. The whirling causes the bottles to assume a horizontal position, so the fat collects in the neck, which is graduated, and the percentage can easily be read.

The sulphuric acid aids separation of butter-fat in three ways :

(1) Being nearly twice as heavy as water, it increases the weight of the milk-serum, making a greater difference between the density of the serum and that of butter-fat.

(2) The acid destroys the stickiness of the milk solids, setting the fat-globules more free to collect in the neck of the bottle.

(3) The mixing of acid with milk causes heat, which facilitates separation.

Apparatus used in the Babcock Test.

(1) **The Pipette.** This is used for measuring the required quantity of milk ; that is, 18 grms. or 17·6 c.c. The pointed end is first placed well into the milk, which is then sucked up till the pipette is almost full. The forefinger, which must be dry, is quickly placed over the top of the pipette ; then, by slightly releasing the pressure, the milk is allowed to run down to the 17·6 c.c. mark. The milk is then run into the test-bottle, which should be held obliquely so that the milk can flow gently down the side and not choke in the neck.

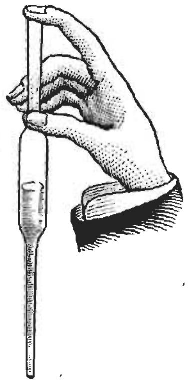

FIG. 29.—USING A PIPETTE.

Remove the last few drops by blowing. Some practice is required before one can manipulate the pipette properly.

(2) **The Test-Bottle.** The test-bottle is provided with a thin neck, which is graduated upwards, from 0 to 10. Each of these divisions denotes 1 per cent. of fat, and each of the five smaller parts into which it is divided denotes 0·2 per cent. The special forms of test-bottle which are used for testing cream and skim-milk will be described later.

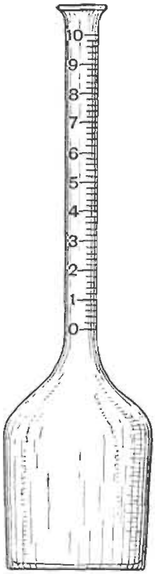

FIG. 30.—THE BABCOCK TEST-BOTTLE FOR MILK.

(3) **The Acid-Measure.** This is a small glass cylinder made to hold 17·5 c.c. of sulphuric acid, which is the quantity required for the test. It is best to fill the measure from a small beaker, because the large acid bottles are too clumsy for careful pouring. Sometimes the acid is measured into the test-bottles from a burette. This is a graduated tube, pointed and provided with a stop-cock at the lower end. It is divided either into cubic centimetres, or, if made specially for milk testing, into divisions of 17·5 c.c. each. The burette measures the acid more quickly and with less danger of spilling than the measuring-cylinder.

The Tester. The centrifugal machine used for whirling the test-bottles is made in various patterns and sizes.

One of the simplest forms is shown in the accompanying sketch. On the top of an upright spindle is fixed a horizontal metal disc to which two swinging pockets are attached. The mechanism in the lower

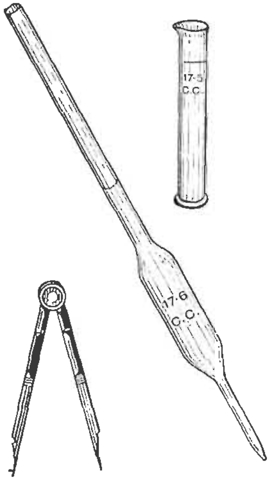

FIG. 31.—PIPETTE, ACID-MEASURE, AND DIVIDERS.

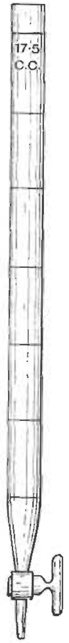

FIG. 32.—A BURETTE FOR MEASURING OUT 17.5 C.C. OF SULPHURIC ACID. Each division holds 17.5 c.c.

part of the machine is so arranged that 100 turns of the handle will cause the pockets to revolve at the rate of about 1000 revolutions per minute. But the number of revolutions required varies according to the diameter of the disc to which the pockets are attached. For example, a disc of 10 inches in diameter requires

1075 revolutions per minute, an 18-inch disc 800, and a 24-inch one only 693. The smaller the diameter, the greater the speed. The speed at which a tester should be run, however, is generally marked clearly upon it, and should be carefully maintained. If the rate of whirling be too slow, the butter-fat is not properly separated, and the reading is lower than it ought to

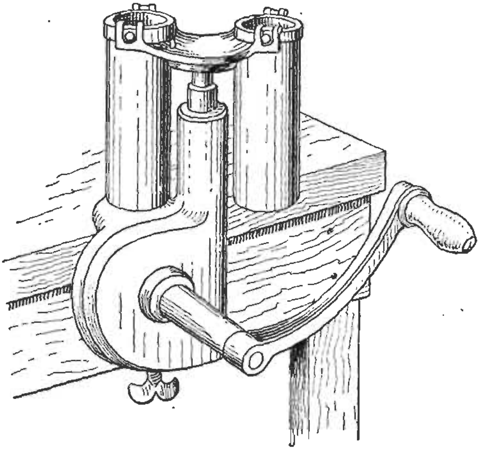

FIG. 33.—A TWO-BOTTLE BABCOCK CENTRIFUGAL MACHINE.

be; if too quick, there is danger of some parts giving way under the tremendous strain, with serious results to the operator.

While the machine is at rest, the pockets hang downwards, but during whirling they assume a horizontal position, causing the fat-globules to collect in the graduated neck of the test-bottle.

Larger testers are made to hold a hundred bottles or more. These are enclosed in a metal case to prevent serious results in case of accident, and also to prevent

loss of heat. It is always advisable to fill up the pockets with hot water, so that the fat will not become cold and harden. The hot water is not required in the case of machines worked and kept hot by means of steam. These, however, are generally found only in factories, where many tests have to be made.

The tester should run smoothly, with the minimum of vibration and no jarring. Violent shaking makes accurate testing impossible. For this reason, machines should be fixed level and on a solid foundation. As a rule, high-standing machines are to be avoided, being generally more apt to shake than low ones. If only a few bottles of milk are to be tested, they should be put into opposite pockets around the disc, in order to balance the machine properly. When only one sample is to be tested, a test-bottle of water can be put in the opposite pocket; otherwise, the tester will not run as smoothly as it ought.

Method of Testing.

(1) *Thoroughly mix the sample of milk to be tested.* This can be done by stirring, or by pouring from one vessel into another several times. The temperature of the sample must be between 60 and 70 degrees Fahr.; about 65 degrees is best.

(2) *Quickly fill the pipette to the* 17·5 c.c. *mark.* This must be done immediately after mixing the milk to be tested.

(3) *Allow the milk to flow into the test-bottle.* Hold the bottle obliquely so that the milk will run down the side and not choke in the neck. Give the pipette time to drain, and remove the last few drops by blowing through it.

(4) *Fill the acid-measure with acid to the* 17·5 c.c. *mark, and add it to the milk.* The temperature of the acid

should be about 65 degrees Fahr. Whilst adding the acid, slowly rotate the test-bottle, so that any milk which adheres to the neck of the bottle may be washed down.

(5) *Thoroughly mix acid and milk.* This is done by giving a quick rotary movement to the test-bottle, which must be continued until the whole mass is dissolved. When the mixing appears to be complete, let the bottle stand for a minute or two. Then rotate again so as to make quite sure that no particles of casein remain undissolved.

(6) *Place bottles in the tester.* If only a few samples are to be tested, see that they are placed in opposite pockets so as to balance the machine. In the case of hand testers, especially in cold weather, fill the pockets with hot water. Replace the cover on the jacket if the machine is fitted with one.

(7) *Whirl at proper speed for five minutes.* Commence and cease whirling gradually, and without any jarring. Use a watch to see that the correct speed is maintained. This whirling brings the fat to the top of the mixture in the test-bottle.

(8) *Add enough water to bring the fat up to the bottom of the neck.* The temperature of the water should be 140 degrees Fahr. at least. The water can be added either from a pipette or from a small lipped beaker.

(9) *Whirl for two minutes.*

(10) *Add sufficient hot water to bring the top of the fat up to the 8 or 9 per cent. mark.*

(11) *Whirl for one minute.*

(12) *Remove the bottle from the tester and read the percentage of fat.* The reading should be made before the fat has time to cool. If there are many tests to be read, place the bottles in hot water until they are required, so as to keep them at about 140 degrees Fahr.

The Acid used. As noted above, the temperature of the sulphuric acid ought to be about 65 degrees Fahr. It is most important that it should be of the right

strength, having a specific gravity of not less than 1·82 or more than 1·83. That is, it must be 1·83 times as heavy as water, bulk for bulk.

Testing the Strength of Acid. (1) This can be done by using a special form of hydrometer known as the "acidometer." In acid of the proper strength at 60 degrees Fahr. it should sink to between the 1·82 and 1·83 marks. This is the most convenient way, and the most reliable, if the acidometer has been properly tested.

(2) Another method is as follows:

Take a dry test-bottle and weigh it. Fill it with the acid up to the zero mark, and find the weight. Subtracting from this the weight of the empty bottle, get the weight of the acid. Empty out the acid, fill with water to the same mark, and similarly find the weight of the water. Divide this into the weight of the acid. The result will give the specific gravity of the acid. Great care must be exercised in measuring out and weighing the liquids, or the result will not be trustworthy.

Diluting Acid. If the acid is too strong, *never add water to it*, or a dangerous explosion will be the result, scattering the powerful acid over your hands and clothes. A safe method is to pour the acid gradually into a little water, keeping it well stirred during the mixing.

Another way is to leave the bottle open for some time. The acid absorbs moisture from the air and becomes considerably diluted, especially in a moist atmosphere.

If the acid is too weak, a little more than the proper quantity should be used in testing.

The better way, however, is to bring it up to proper strength by the addition of stronger acid.

Action of the Acid. When added to milk, sulphuric acid precipitates the casein into a solid mass, but, by agitating the mixture for a few minutes, we can easily re-dissolve the casein. The dark brown colour is caused by the acid burning some of the milk-solids. As mentioned in the beginning of this chapter, sulphuric acid aids the separation of fat from milk-serum (1) by overcoming the stickiness of the milk-solids and setting the globules more free to collect in the neck of the test-bottle, (2) by increasing the density of the milk-serum, and (3) by providing heat.

Precautions. (1) *Never pour water into acid.*

(2) Keep the stopper in the acid bottle.

(3) Be careful not to spill the acid : if you do, wash it off immediately with plenty of water.

(4) Never pour acid into a tin or metal dish.

The Water used. When water is added to the test-bottle, care must be taken not to raise the liquid above the 10 per cent. mark. Its temperature should not be less than 140 degrees Fahr. If possible, use distilled water ; if this is not at hand, soft rain-water will do instead. Hard water may spoil the test, although the hardness can often be overcome by boiling or by adding a few drops of sulphuric acid.

Reading the Test. (1) Hold the test-bottle upright, and on a level with the eye. Note the upper and lower limits of the fat-layer very carefully. Then, by subtracting the lower reading from the upper, the percentage of fat is easily obtained.

(2) Sometimes dividers are used to save this calculation. One of the points is placed at the bottom of the fat-column, and the other at the top. Then, by bringing the lower point of the dividers to the o mark, the other one is placed at the number giving the percentage of fat, which can easily be read off. This is made clear by Fig. 34.

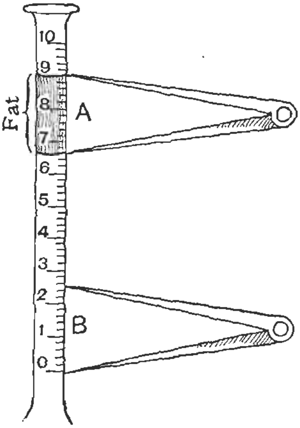

FIG. 34.—READING THE FAT-COLUMN BY MEANS OF DIVIDERS.
A. First position.
B. Second position.

(3) The upper surface of the fat-column will not be straight, but curved, and lower in the middle than at the sides. The reading must be made at the *highest* point of this curve, where it meets the side of the neck, not at the bottom or midway between. In the case of the lower reading, take the *lowest* point of the fat. This method of reading gives a slightly higher percentage of fat than is actually present in the neck of the test-bottle, but it is really correct, because a small proportion of fat always remains unseparated from the mixture of acid and milk-serum, and this is just the amount of error made by reading at the extreme limits of the fat-column.

(4) The appearance of foam on the top of the fat is caused by the use of hard water, and makes accurate reading impossible. The difficulty can be overcome by adding two or three drops of methylated spirits just before reading.

White particles of undissolved casein indicate weak acid, too little acid, too low a temperature of milk or acid (below 60 degrees Fahr.), or improper mixing.

Black particles or dark fat are due to too much acid, too strong acid, too high a temperature, or allowing the acid to fall into the milk instead of pouring it down the side of the test-bottle.

Care of the Apparatus. All glassware must be kept scrupulously clean. Test-bottles should be emptied immediately after use, before the fat has time to harden. A little shaking will remove the white sediment of gypsum from the bottom. The bottles should then be allowed to soak in a pail of hot water containing soda or washing-powder. Clean the insides by means of a test-bottle brush, rinse thoroughly in hot water, and place the bottles in a rack to drain. A simple draining-rack can be made by boring holes through a piece of board, and placing it over a wide jar to catch the drippings.

The Accuracy of Test-Bottles. A properly-graduated test-bottle should hold exactly 2 cubic centimetres between *the 0 and 10 marks on its neck*.

There are several methods of testing the accuracy of these 10 per cent. test-bottles.

One method is as follows:

Allow exactly 2 c.c. of mercury to run into the test-bottle from a burette. Then push a cork down the neck of the bottle to the 10 per cent. mark. (The cork should be cut perfectly level at the bottom and fit the neck well.) Invert the bottle, and allow the mercury to run into the neck. If the mercury exactly fills the space between the zero and the 10 mark, the bottle is graduated accurately.

Another method is to use water, preferably coloured. Put into the bottle sufficient of the water to reach to the 0 mark. Remove all moisture from the inside of the neck with a strip of blotting-paper. Then allow exactly 2 c.c. of water to run into the bottle from a burette. If the bottle is graduated correctly, this water should just fill the space between the 0 and the 10 mark.

Sometimes, instead of adding the 2 c.c. of water, a metal plunger is lowered into the neck. The volume of the plunger is 2 c.c., and it should raise the level of the water to the 10 mark.

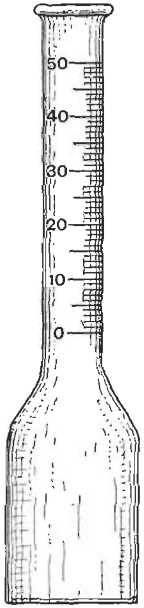

FIG. 35.—BABCOCK TEST-BOTTLE FOR CREAM.

The Test for Cream. The Babcock test can also be used for finding the amount of butter-fat in cream, skim-milk, whey, butter, and other milk-products, but it will not be necessary for us to consider more than the first two at present.

The test for fat-percentage in cream depends upon exactly the same principles as in the case of milk, but one or two of the details are different on account of the peculiar properties of cream.

The Test-Bottle. First of all, we do not use the ordinary test-bottle for testing cream because, you will remember, its neck is graduated to measure only up to 10 per cent. of butter-fat, and cream may contain anything from 20 to 45 or 50 per cent. So a special

test-bottle has to be used, with a neck large enough to hold a much greater quantity of fat than the neck of the milk test-bottle can. Sometimes bottles with extra long necks are used, but they are not suited for ordinary centrifugal machines, and so the commoner type of cream bottle is one with a very wide neck, which is usually graduated up to 50 per cent.

Cream tests should be read at a temperature of between 130 degrees and 140 degrees Fahr.

If the cream to be tested is very rich, it can be divided into two equal portions. After adding enough water to make each up to about 17·6 c.c., we test the two portions separately, and then add the two readings to get the actual fat-percentage of the sample. Another common method is to test only 9 grams of cream and then multiply the percentage of fat by 2.

Measuring the Cream. The quantity of acid and the graduations on the neck of the test-bottle are arranged so as to give an accurate test when exactly 18 grams of milk, or cream, are used. 17·6 c.c. of milk weigh 18 grams, and so we use a 17·6 c.c. pipette for measuring the milk to be tested. But cream is considerably lighter than milk because of the greater quantity of fat it contains. Consequently, 17·6 c.c. of cream will not weigh 18 grams; in the case of very rich cream it may weigh only 17 grams, or even less. Very often, too, cream contains a great number of minute air-bubbles, and these all tend to make it lighter; this is especially the case with separator cream. Therefore, we must not use the 17·6 c.c. pipette for measuring the cream for testing, neither is it possible to have a special pipette made, because

the specific gravity of cream varies just as its fat-percentage varies. We must get the 18 grams of cream *by weighing*. To do this, place the test-bottle in one of the scale pans, and exactly balance it by weights in the other. Then add an 18 gram weight and carefully pour the cream into the bottle until the two sides are exactly balanced again. Care must be taken not to spill any of the cream either into the pan or on to the outside of the test-bottle.

Sampling the Cream. The cream must be thoroughly mixed before the sample is taken, because the fat-globules will always rise to the top and make the cream uneven, if it is allowed to stand. Heating the cream up to 105 degrees or 110 degrees Fahr. makes it easier to mix. If it is at all clotted, it should be run through a small sieve, and then poured from one vessel into another two or three times before the sample is drawn out. In milk testing the bottles are whirled for five minutes before the hot water is added, but in cream testing this is liable to give cloudy results. It is much better to add the hot water as soon as the cream and acid are mixed, and then whirl for the five minutes. The fat-column should be bright golden in colour.

The fat-percentage must be read with great care, as the graduations are very close together on account of the width of the neck. The ordinary wide-necked cream bottle is graduated correctly to 0·5 per cent., and this is quite accurate enough for ordinary purposes. When very exact results are required, greater accuracy can be obtained by using a long-necked bottle, which is graduated correctly to 0·2 per cent. A little less than

17·5 c.c. of acid should be used in testing cream. The exact amount cannot be definitely stated, as some samples of cream seem to require more acid than others. Sometimes 15 c.c. are sufficient.

Test for Skim-milk. The amount of butter-fat in skim-milk is so small that much greater accuracy is needed in testing for it than in the case of milk ; a very small degree of error will seriously affect the result. When testing whole milk, 0·1 per cent. one way or the other makes little practical difference; but, in a skim-milk test, it may more than double the true reading. On this account we use a special form of bottle for testing skim-milk, buttermilk, and whey. It has two necks—one wide and the other very thin. The wide neck protrudes half-way down into the bottom part of the test-bottle and is used for pouring in the milk, acid, and hot water. The protruding piece at the base of the wide neck is a simple, but very ingenious contrivance for preventing the fat from entering it.

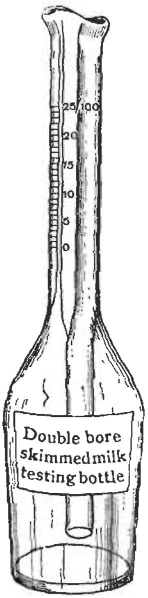

FIG. 36.—SKIM-MILK TEST-BOTTLE.

When hot water is added at the end of the test, the separated fat is driven up into the small neck, and can there be read with accuracy. Each of the divisions denotes 0·05 per cent., and, on account of the thinness of the tube, they are far enough apart to give a reading correct to one-hundredth per cent. The reading is always more or less inaccurate, however, because of

the small quantity of fat which remains in the mixture of acid and milk, and this difficulty cannot be completely overcome.

In order to get a more complete separation of the fat, it is usual to add 20 c.c. of sulphuric acid, and to whirl at full speed for a minute or two longer. The temperature must be kept as high as possible, and not be allowed to fall below 130 degrees Fahr.; for this reason a steam tester is much better than a hand machine.

Skim-milk testing is very difficult for amateurs; even the skilled operator often fails to get a satisfactory result.

Skim-milk bottles are graduated so as to accommodate 0·25 per cent. of fat. Skim-milk from pan-setting generally contains two or three times this quantity of fat, and should be tested with the ordinary milk bottle.

The Gerber Method.

About two years after the introduction of the Babcock test, a simpler method was invented by Dr. Gerber, a Swiss scientist. In Europe the Gerber method is the one most generally employed. Both methods have the same aim (the estimation of fat-content), and both depend upon the same principle (centrifugal force, aided by the action of acid).

The main points of difference are:

(1) The Gerber method requires *two reagents*—sulphuric acid and amyl alcohol; in the Babcock system, sulphuric acid alone is used.

(2) In the Gerber method *no hot water* is added to the test-bottle.

(3) The Babcock system requires three whirlings in the centrifuge; for Dr. Gerber's method only *one whirling* is needed.

(4) Each method requires its own special forms of glassware and other apparatus.

The sample of milk must be taken with the same care as for the Babcock test; it must be well mixed, representative of the whole, and at a temperature between 60 and 65 degrees Fahr. 10 c.c. of sulphuric acid should first be measured with the special pipette and allowed to run into the "butyrometer," or test-bottle. Next add 1 c.c. of amyl alcohol, letting it run down the side of the neck; the object of using amyl alcohol is to prevent charring of the milk-solids by the acid. Then add 11 c.c. of milk in a similar manner. The order in which the three liquids are put into the test-bottle does not matter much, except that it is advisable to put the acid in first. Then screw the rubber stopper into the neck of the test-bottle, and mix the contents by thoroughly shaking. Place the bottle in the centrifuge and whirl for three minutes; the test is then completed. In order to read the fat-column, turn the rubber stopper gently until the bottom of the column is level with one of the main graduations; the percentage of fat can then be read without difficulty.

By this method clear and accurate results can be obtained. That it is so little known in many parts of the world is not due to any fault in the method itself, but rather to the fact that the Babcock system was first in the field.

QUESTIONS ON CHAPTER VII.

1. Summarize briefly the various steps taken in testing milk for butter-fat by the Babcock method.

2. Why is acid used in the Babcock test? What is the effect of using (*a*) too much acid, (*b*) too little acid?

3. Enumerate the points of difference between the method of testing milk and that of testing cream.

4. Describe a milk bottle, a cream bottle, and a skim-milk bottle.

5. How would you test the accuracy of the graduations on a 10 per cent. test-bottle?

6. Explain (*a*) how to use the pipette, (*b*) how to add the acid.

CHAPTER VIII.

CARE AND TREATMENT OF MILK.

If the quality of butter and cheese is to be kept at a high standard, it is necessary that the strictest attention should be paid to the way in which milk is treated from the moment it is drawn from the cow. Many of the undesirable qualities, which often appear in milk-products, are to be traced to carelessness in handling the milk in the earliest stages of the process of manufacture.

To produce good-flavoured butter, we must have milk free from all contamination and of the best quality. Consequently, it is most important that the dairyman should understand the proper method of handling milk from the moment it is drawn from the cow until it leaves his hands.

The Cow-Byre. In the cow-byre, or milking-shed, cleanliness should be the first consideration, although it is very often neglected. Many milkers seem to have the idea that whatever dirt enters the milk in the milking-shed will be removed by the strainer, and so they do not exercise sufficient care. But this is quite wrong, because much of the dirt is immediately dissolved, and harmful bacteria are produced which the

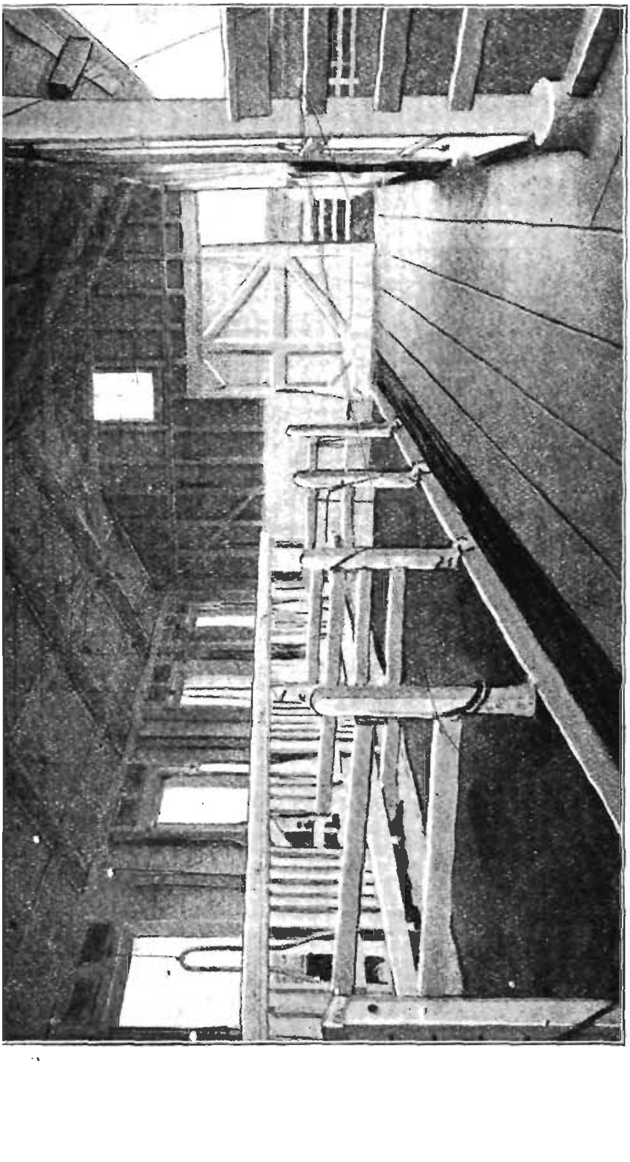

FIG. 37.—INTERIOR OF A MODEL COW-BYRE. (From *N.Z. Agric. Journal.*)

finest strainer cannot catch. They pass through the milk, continue to increase, and produce substances which spoil the flavour and keeping qualities of the butter or cheese which may be made from it. The milking-shed is the place where milk is most likely to become contaminated by bad smells and bacteria.

The Floor. The floor of the shed must never be allowed to become coated with a layer of mud and filth. It must be regularly cleaned after each milking, and so constructed as to make cleaning easy. If possible, the floor should be made of concrete, and slanting towards one side, along which should run a shallow drain. Then, after any solid matter has been raked out, the floor can easily be cleaned by washing it with a hose or by throwing buckets of water over it. On no account must pools of liquid manure be allowed to collect on the floor of the milking-shed. If the floor is made sloping towards a drain, however, and is kept in good repair, this will not occur.

We have all noticed the strong, pungent smell which is common to stables and cow-byres. This is due to ammonia gas and various impurities which rise from decomposing manure; this gas is very soluble and part of it is certain to be absorbed by the milk as it passes through the air, even during the short journey from the cow's teats to the milk-pail. In order to prevent the contamination of milk by these gaseous impurities, many authorities recommend the spreading of gypsum (sulphate of lime) about the floor of the milking-shed, because it readily absorbs the ammonia gas from the air.

Gypsum is itself a valuable manure, but, when enriched by a supply of ammonia, its value as a fertilizer is greatly increased.

Woodwork. The walls of the milking-shed and all woodwork must also be attended to. They should be kept free from dirt, and receive a coating of limewash two or three times a year at least. Lime is very cheap, and, being an excellent disinfectant, it preserves the wood from decay, kills any bacteria which may be harbouring thereon, and sweetens the shed generally.

Milking. Cows should always be kindly treated, especially before and during milking, because a cow will take offence at ill-treatment and cause certain muscles to close up the milk-tubes in the udder, thus preventing the milk from flowing down.

It is also important that the animals should be kept clean, and not be driven through mud if it can be avoided. Many cow-yards are allowed to get very dirty indeed, and in the wet weather are covered with a foot or more of liquid filth ; this sticks to the cows, dries, and probably falls into the milk. If the yard is paved with fairly large stones and sloped so that the water may run off, very little dirt can collect there, because every shower of rain helps to wash it away.

The cow's udder should always be washed before milking, otherwise small pieces of dried mud are almost certain to fall from it into the milk-pail.

Two other points to remember are, to throw away the fore-milk, and to strip clean. The fore-milk consists of the first two or three squeezes of milk from each teat. This milk is very liable to contamination by germs entering it through the teat, and as it contains

about only 1 per cent. of butter-fat, little is lost by always rejecting the fore-milk.

Thorough stripping is important for several reasons: (1) the "strippings" are the part of the milk richest in butter-fat; (2) clean stripping develops the udder; and (3) it helps to keep up the milk-yield.

Before commencing to milk, the milkers should always wash their hands; they ought not to wear the oldest and dirtiest clothes obtainable, but clean overalls, which should be kept specially for the purpose and regularly washed. Sometimes, when there is difficulty in milking through soreness of the cow's teats, a little vaseline may be rubbed over the teats after they have been washed. Milkers should never use the fore-milk for moistening the teats. As soon as possible after it is drawn from the cow, the milk should be taken out of the milking-shed, and allowed to stand in some clean place where there will be no possibility of its becoming "flavoured" through the absorption of bad odours.

Flavours in Milk. We frequently meet with milk, and butter also, which possesses some unusual flavour; this is due to the fact that milk is very absorbent and very readily becomes tainted. The objectionable flavours which occur in milk may be divided into two classes: (1) Food flavours, and (2) flavours due to contamination.

Food flavours are due to the use of certain strong foods such as rape, turnips, cabbage, or musty ensilage, which impart their characteristic flavour to the milk. Very often the pasture contains a large number of strongly-flavoured weeds, such as dandelions and penny-royal, and these give the milk a slightly bitter

taste. If the strongly-flavoured foods mentioned above are not given to the cows for eight or nine hours before milking, the substances which cause the objectionable flavours will be passed out of their bodies in various ways, and hardly be noticed in the milk, if at all. Thorough aeration of the milk by letting it fall through fresh air has the same effect.

A third method of overcoming food flavours is pasteurization. By heating to a fairly high temperature, such as 196 degrees Fahr., and then suddenly cooling, the objectionable flavours can be driven out of the milk.

It is often difficult to avoid using strongly-flavoured foods; if proper precautions are taken, however, the quality of the milk or butter should not be injured.

Contamination flavours are caused by dirt, and the one remedy is cleanliness. Sweet milk cannot be expected from cows which are forced to drink impure or stagnant water. Harmful bacteria which enter the milk after it is drawn from the cow frequently cause unpleasant and unhealthy flavours. By paying strict attention to cleanliness, however, contamination flavours can be completely avoided.

Care of Utensils. Every dairy should be supplied with proper conveniences for cleaning the various utensils, so that the work may be done thoroughly and with the minimum of labour. Brushes are much better than cloths; they remove the dirt from all cracks and can themselves be kept clean more easily than cloths. Nothing provides a better breeding-place for germs than a dirty cloth.

Cans should be washed in tepid water before they are scalded. This is because hot water causes the albumen to coagulate and form a scum which is difficult to remove. After tepid water, hot water containing a little soda or lime will remove any fat still sticking to the can. A good rinsing with clean boiling water should then be given, and the cans placed in the sun to dry. They should not be dried with a cloth ; the water will be evaporated by its own heat. For washing purposes, as well as for drinking, a supply of pure water is essential.

Straining and Aerating. As soon as it leaves the milking-shed, the milk should be strained. This is done by pouring it through a fine metal strainer, which removes any solid particles of dirt. Bacteria and dissolved dirt, however, the strainer cannot catch. A fine cloth strainer is used to remove the very minute particles ; it must always be sterilized by boiling before it is used, as a dirty strainer is worse than useless.

Aerating consists of exposing the milk to the air. It is sometimes effected by letting the milk fall through several strainers, so that the air may reach every part of it. If done in pure air and a cool place, aerating is beneficial, because it allows food flavours to escape and, by hastening the cooling, retards the growth of germs. Generally the aeration is done during cooling. As the milk runs over the surface of the cooler, it receives a thorough airing. Aerating in a hot or impure atmosphere does nothing but harm.

Cooling. All milk should be cooled as soon as possible after milking (that is, if the cream is to be obtained by setting in pans). When a separator is

used, the cream should be brought down to ripening-temperature (60 to 65 degrees Fahr.) immediately after separating. As already explained, rapid cooling is important, because a low temperature prevents the increase of bacteria in the milk. When milk is intended for sale, it should be cooled to 50 degrees if possible.

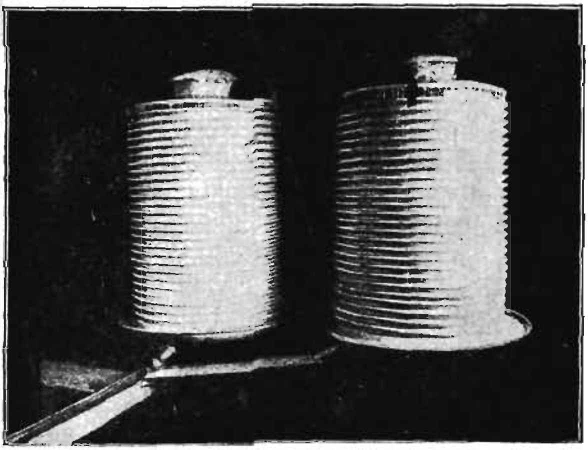

FIG. 38.—CIRCULAR COOLERS AT WORK.

This can be done by placing the cans of milk in tanks of cold water or by letting the milk run over a cooler.

There are many different types of coolers ; a common one is shown in Fig. 38. It consists of a circular tank having corrugated sides. Fixed on the top is a small circular receptacle for the milk ; it has holes all round through which the milk is distributed over the cooler. The milk flows down the side, and, in its course over the corrugations, receives a thorough chilling and aerating. A reservoir should be fixed above the cooler to supply

it with a regular flow of milk. Meanwhile, cold water is allowed to run continuously through the tank.

Another kind of cooler is shown in the next illustration. It is made of a series of parallel pipes connected together, through which cold water is kept running. At the top of the cooler is a small trough with holes

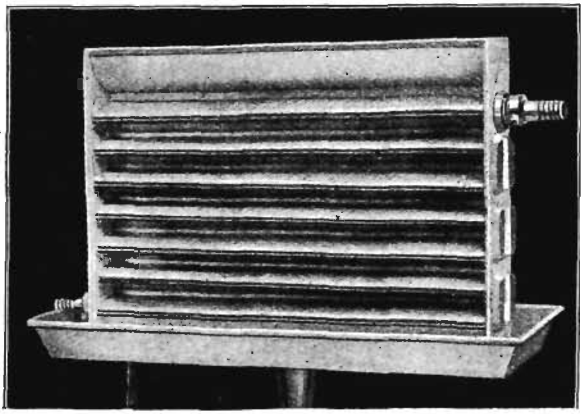

FIG. 39.—A MILK COOLER.

in the bottom, through which a steady supply of milk runs down on to the cold-water pipes. These pipes are flat on the top and inclined slightly towards one end, so that the milk will run gently along them and get the full benefit of the cold water inside.

QUESTIONS ON CHAPTER VIII.

1. What sanitary precautions should be observed during milking?

2. If milk is to be creamed by pan-setting, describe how it should be treated from the time it is drawn from the cow until it is set in the pans. State the reasons for the various processes employed.

3. What is meant by " flavours " in milk ? How are they caused, and how may they be overcome ?

4. Explain the method of washing dairy utensils.

5. State definite rules for keeping the milking-shed in a sanitary condition.

CHAPTER IX.

BUTTER-MAKING.

BEFORE we study in detail cream-ripening, churning, and the other things involved in butter-making, it will be well for us just to take a general glance at the whole process. From the time the milk is drawn from the cow until it is made into properly-finished butter, we meet with the following steps :

(1) Straining.
(2) Aerating.

A. { (3) Cooling the milk. (4) Setting in pans. (5) Ripening. (6) Skimming. } *Old Method.*

or, if a separator be used, we have instead of the last four processes :

B. { (3) Separating. (4) Cooling the cream. (5) Setting the cream. (6) Ripening of cream. } *New Method.*

(7) Churning.
(8) Washing.
(9) Salting.
(10) Working.

The four steps bracketed and lettered " A " are taken when the cream is obtained by the old method of pan-

setting. The milk is cooled, set in pans, and the cream is skimmed off usually after twenty-four hours; by this time it is ripe enough for churning—sometimes too ripe.

If a separator is used, the four processes bracketed under "B" are gone through instead. Cream is obtained by the separator immediately after milking, before the milk has time to cool. It is then cooled down quickly to 60 degrees Fahr., and is placed in pans to ripen. Both methods give us the same ultimate result—ripened cream, but in different ways.

FIG. 40.—LACTIC-ACID GERMS.

The first few steps in the process of butter-making—straining, separating, aerating, and cooling—have already been dealt with. The remaining steps are also very important, and must be studied in detail. They are: cream-ripening, churning, washing, salting, and working.

Cream-ripening. Before making butter it is customary to allow the cream to ripen, although it is quite possible to make butter from fresh cream. Ripening is caused by the action of lactic-acid bacteria. As is to be expected, ripening is quickest when bacteria develop most rapidly; that is, when cream is warm—between 90 and 100 degrees Fahr. The usual ripening-temperature, however, is between 60 and 65 degrees. The purpose of this low temperature is to allow the lactic-acid bacteria to ripen the cream, and at the same

time to prevent the growth of harmful bacteria and ferments, as these form undesirable products which may seriously injure the quality of the butter. Sometimes a supply of lactic-acid bacteria (a "starter") is added to the cream in the form of a little sour but wholesome milk, and this helps on the process of ripening. In many places it is customary to destroy completely all bacteria in the cream by pasteurizing it, and then to add a fresh supply of lactic-acid bacteria. Cream must not be allowed to get too ripe, or the flavour of the butter will be spoiled.

The Effect of Cream-ripening. The ripening of cream not only makes churning easier and more exhaustive, but also has a great deal to do with the flavour of the butter which is made from the cream.

Consequently, the dairyman ought to be familiar with, and should use, the various means of controlling cream-ripening, instead of leaving it to chance, as is so often the case. If cream is allowed to get too ripe, it makes butter with a strong, sour flavour. Stale cream is the cause of stale-flavoured and rancid butter. If cream has become contaminated by the absorption of harmful bacteria, good butter cannot be made from it, because the bacteria produce various compounds which impart a disagreeable taint to the butter. Here, again, we are brought face to face with the fact that faults in the finished product are very often due to careless handling in the early stages of manufacture. If cream is not allowed to get sufficiently ripe, the butter made from it has a flat, insipid flavour. This is because not enough lactic acid has been produced to give it the degree of sharpness which the popular palate demands.

When cream is obtained by pan-setting, it is generally ripe enough for churning at the time of skimming; that is, after about twenty-four hours. By this time *it has become thick* or viscous in appearance and slightly sour to taste and smell.

Methods of Cream-ripening. There are many different methods of cream-ripening, but it will be sufficient for us to consider just two or three of the principal ones.

(1) **Natural Ripening.** If cream is allowed to stand for a time in pans, it will soon begin to ripen of its own accord; this is the simplest, although not the best, method of cream-ripening. Cream is ready for churning after standing about twenty-four hours at a temperature of between 60 and 65 degrees Fahr. The process of ripening is set up by germs in the cream; some of them were there when the milk was drawn from the cow; others have entered during subsequent handling. These germs may be divided into two classes, viz. (1) lactic-acid-forming, and (2) putrefactive.

The action of the former has already been described. They convert milk-sugar into lactic acid, which, when present in proper quantities, gives butter an agreeable flavour.

The putrefactive germs set up a process of decay, and form harmful compounds. They turn milk *bad*; the lactic-acid bacteria turn it *sour*. Unless special care is taken, large numbers of putrefactive bacteria may gain access to the milk and more or less injure the flavour and keeping qualities of the butter. For this reason the natural or "chance" system of ripening cannot be relied upon. It is much better to employ

a method which gives the dairyman greater control over the process of ripening.

(2) **Starter Ripening.** The use of "starters" is a means by which cream-ripening can be controlled and made to give good results. A starter is a quantity of milk which contains a high percentage of lactic-acid germs. It is prepared by first pasteurizing milk to destroy all bacterial life, and then adding a pure culture of lactic-acid bacteria to it. In this way we can obtain milk entirely free from all putrefactive bacteria, but well supplied with those organisms which are required for "healthy" ripening. When the starter is added to cream, the lactic-acid-forming germs immediately begin to increase rapidly. Being present in large numbers, they soon predominate over any putrefactive bacteria which may be present, and so restrain the bad influences of the latter. As soon as the cream is taken from the separator, it should be cooled rapidly to 60 degrees or 65 degrees Fahr., and the starter added immediately. Rapid cooling prevents the fermentation which sets in quickly when milk is warm; adding the starter immediately gives the lactic-acid germs a chance of developing early and of so gaining predominance over any harmful bacteria which may be in the milk.

As a rule, the amount of starter added should not be more than 3 per cent. of the cream; sometimes, when the cream is tainted, as much as 5 per cent. is added in order to hasten on the formation of lactic acid. It is much better, however, to avoid using a high percentage of starter by keeping the cream free from all contaminating influences. Too much starter is likely to cause over-ripening, owing to excess of acid

produced, and rancid or fishy flavours in the butter are the result.

The cream should be thoroughly stirred when starter is added, so as to distribute it properly. It should also be stirred at intervals during the whole time it is standing in order to ensure uniform ripening. The development of lactic acid can be ascertained from time to time by use of the acidometer test (see Chap. XI.). If it is found that ripening is progressing too rapidly, over-production of acid can be prevented by reducing the temperature. The better way, however, is to find out the exact quantity of starter necessary to bring about proper ripening in the time during which the cream is to stand, and to keep to the proper temperature (60 to 65 degrees) throughout.

Too low a temperature is likely to result in unsatisfactory ripening.

(3) **Pasteurized Cream-ripening.** If we use starters, we can get much better results than by simply allowing cream to ripen naturally, but a further improvement can be effected by pasteurizing the cream and so destroying all the bacteria in it before the starter is added. When this system of pasteurized cream-ripening is employed, the cream should first be heated to between 160 and 170 degrees Fahr., and then suddenly cooled down to ripening-temperature (65 degrees Fahr.). The starter is then added, care being taken to see that the cream has been properly cooled before doing so. The lactic-acid-forming bacteria are thus given every opportunity of performing their work without any interference on the part of harmful putrefactive bacteria. No disagreeable products are

formed by undesirable germs ; it is never necessary to use more than the proper quantity of starter in order to overcome taints in the cream ; the dairyman is able to control the process of ripening much more thoroughly than he is when the cream is not pasteurized ; and a better flavoured butter is the result.

A full account of the preparation and use of starters is given in Chapter XII.

Churning. The object of churning is to collect into a solid mass the fat-globules which are in the cream. When the cream is agitated, the globules are knocked together. This causes them to stick together in clusters, forming irregular masses of fat known as "butter-granules." Butter consists of these granules pressed closely together.

The following simple experiment will show what takes place when cream is churned.

Take an ordinary school slate and some mercury, or quicksilver. Lay the slate flat on a table and drop mercury on to it from a height of about fifteen inches. The force with which it meets the slate breaks up the mercury into a large number of small particles which spread over the slate. These particles of mercury represent the fat-globules in cream. Now gently shake the slate to and fro ; the globules of mercury run together and form larger masses, just as the fat-globules form granules when cream is churned.

The Churn. There are so many different kinds of churns in use that to give an account of them all would be a very big task indeed. The ideal churn is the one against the sides of which the cream may be dashed with the maximum amount of concussion and the minimum

expenditure of labour. In order to increase the concussion, many churns have pieces of wood called "dashers" inside; the purpose of these is to beat against the cream and so knock the fat-globules together. Sometimes the body of the churn remains still while the dashers are made to revolve inside by means of a handle. In other types of churns the dashers are fixed and the body revolves. Many churns have no dashers at all, and are quite plain inside. Perhaps the best churn of all is the common barrel churn working

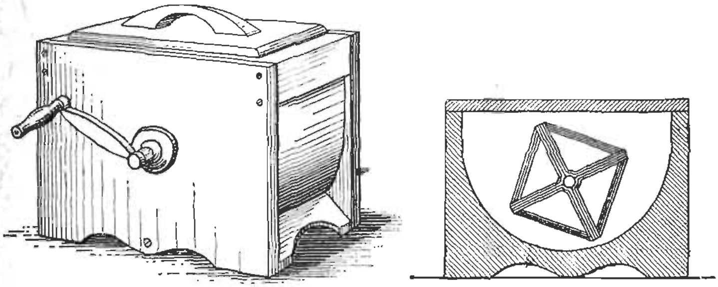

FIG. 41.—A "DASH" CHURN. Section, showing dashers, on right.

end over end, and having no dashers inside. This is the kind which seems to be most favoured by experts.

The revolving box churn, and the old-fashioned round churn with revolving dashers are other well-known types. Of these two, the former is to be preferred. It is the more easily worked, and the cream is dashed with considerable force against the perpendicular sides, although the concussion is not so great as in the barrel churn.

Speed of Churn. The rate at which a churn should be turned depends a good deal upon its shape. As a rule, it should be from 40 to 45 turns to the minute.

The purpose of regulating the rate of turning is to make the cream dash against the sides of the churn with the greatest amount of concussion possible. To a certain extent, the quicker the churn is turned, the greater will be the concussion, but, if it is turned too quickly, the cream will be *held to* the sides by centrifugal force. This prevents the cream from being *dashed against* the sides, and so the effect of turning too rapidly is not to hasten churning, but to prolong it.

The correct speed is generally marked on the churn ; if it is not, about 40 turns a minute should give satisfactory results.

The Cream.—(*a*) **Acidity or Ripeness.** As already stated, it is quite easy to make butter from fresh cream, but ripened cream is nearly always used. It is found that the ripening not only improves the flavour of the butter, but also gives a more exhaustive churning, thus saving loss of fat in the butter-milk.

Cream should be churned when it contains 0·5 per cent. of lactic acid ; it is then thick like syrup and has a glossy appearance when stirred. If the cream is allowed to ripen naturally, the necessary amount of acid is generally produced in twenty-four hours.

(*b*) **Temperature.** The temperature at which cream should be churned is a very important item, and every dairy should include an accurate thermometer in its equipment, so that the cream can be brought to the proper temperature before churning. The higher the temperature of the cream, the more readily the fat-globules unite, and the more rapid the churning. So, in this respect, it is an advantage to have the cream fairly warm. On the other hand, however, too high

a temperature is likely to cause softness and a large amount of moisture in the butter. If the temperature is too low, the churning is prolonged, and this also may injure the butter. Consequently, we must learn how to get that temperature, which, being neither too high nor too low, will give the best possible results.

It has been found that, to obtain the best results, the cream should "break" after 35 or 40 minutes' churning. When the granules of fat separate from the buttermilk much before 35 minutes or much after 40 minutes, we generally find that there are defects in the butter, and that a fairly large amount of fat is wasted through not being separated from the buttermilk. If we remember that a high temperature hastens churning and a low one retards it, we can easily have the churning completed in the desired time; to shorten the time we merely raise the temperature, to increase the time, we lower it. The most suitable temperature is that which will cause the cream to "break" after 35 or 40 minutes' churning. One cannot name any definite number of degrees as the exact temperature to give this result, because some lots of cream churn more readily than others, and the temperature has to be regulated accordingly; it depends upon the condition of the cream.

We must now briefly consider those things which influence the condition of the cream, because they may cause the churning-temperature to vary as much as 10 degrees.

The most important of them are the stage of lactation, the age and breed of the cow, the fodder used, and the richness and acidity of the cream. One of the reasons

for having rich cream is that it churns more readily than a thin one, and so enables us to use a lower churning-temperature; ripening has the same effect.

At the commencement of the milking season, when the cows have just calved, cream is churned at about 55 degrees Fahr., but towards the end of the period of lactation, the temperature should be raised to 64 or 65 degrees. There are two important reasons for this change as the season passes from spring to winter. The first is that, as the period of lactation advances, the fat-globules gradually decrease in size, and so it becomes more difficult to knock them together into granules; to overcome this difficulty, we use a higher temperature.

The other reason is that in spring the butter-fat is comparatively soft, but it gradually becomes harder and more difficult to melt towards the end of the season. In order to make butter, it is necessary to have the fat partly melted, and so, as the fat gets harder, the temperature of the cream must be raised. Hard fat is also produced by hard feed; rich, succulent pastures make softer fat, which melts at a lower temperature.

By this time the reader will have discovered that the question as to what is the best churning-temperature is by no means a simple one. In practical butter-making the aim should be to make the churning occupy about 40 minutes; in order to do this it will be necessary gradually to increase the temperature of the cream from about 55 degrees to 64 degrees as the stage of lactation advances.

The Churning. The churn should be washed with scalding water and then thoroughly cooled again by

rinsing it several times with cold water before any cream is poured in. All other wooden utensils which are used for handling butter should be treated in the same way, because it removes any dirt and prevents the butter from sticking to the wood. The next thing is to see that the cream is at the correct temperature for churning. If the temperature is much above or much below what it ought to be, the cans of cream should be placed in cold or hot water respectively, and kept stirred until the right temperature is reached. The cream is then run into the churn through a fine strainer. Any lumps of cream which may be caught should be broken up and rubbed through the strainer; if this were not done the lumps would show up as mottles in the butter. The churn must never be more than half full, because the greater the quantity of cream, the smaller the force with which it meets the sides of the churn; if the churn is much less than half full, it is advisable not to turn so quickly.

After the first few turns, the churn should be stopped, and the plug taken out. This is because a considerable quantity of gas will have formed inside, and it should be allowed to escape. After a few moments the plug is replaced, and the churning is continued at the correct speed for about 35 minutes. At the end of that time, the butter should "come." As soon as the peculiar splashing sound of the cream "breaking" is heard, the churn should be stopped. The fat-globules have collected together in small irregular masses known as "butter-granules." At this stage it is best to pour a little cold water into the churn, because it helps separation and prevents too much buttermilk from

getting into the butter. The temperature of this water should be 5 or 6 degrees lower than that of the cream ; this is an important point because, if the water is either too warm or too cold, it will very likely spoil the texture of the butter, and also cause it to contain too high a percentage of moisture. Then continue the churning. The granules gradually increase in size until, after about 5 minutes, they are the size of wheat grains, and rough in appearance. The churning is now completed, so stop the churn and allow the buttermilk to run out through a sieve. Most of the granules will be left behind in the churn as lumps of fat, but any loose ones which may be in the buttermilk are caught in the sieve and then returned to the churn.

Washing. Although it is usually done in the churn, washing is a very different thing from churning. Its purpose is to wash the lumps of fat free from all buttermilk. Buttermilk is practically the same thing as skim-milk, although it is obtained in a different way. As soon as the buttermilk has been taken from the churn, pour in about the same quantity of cold water. Then revolve the churn a few times and draw off the wash-water immediately. If the butter is too soft, as is generally the case when the cream has been churned at too high a temperature, it will be necessary to repeat the washing. But we must always try to avoid over-washing, because it takes both the flavour and the aroma from the butter ; for the same reason, butter must never be allowed to lie in the wash-water longer than necessary. When the water has run out, allow the butter to drain for a minute or so, and then

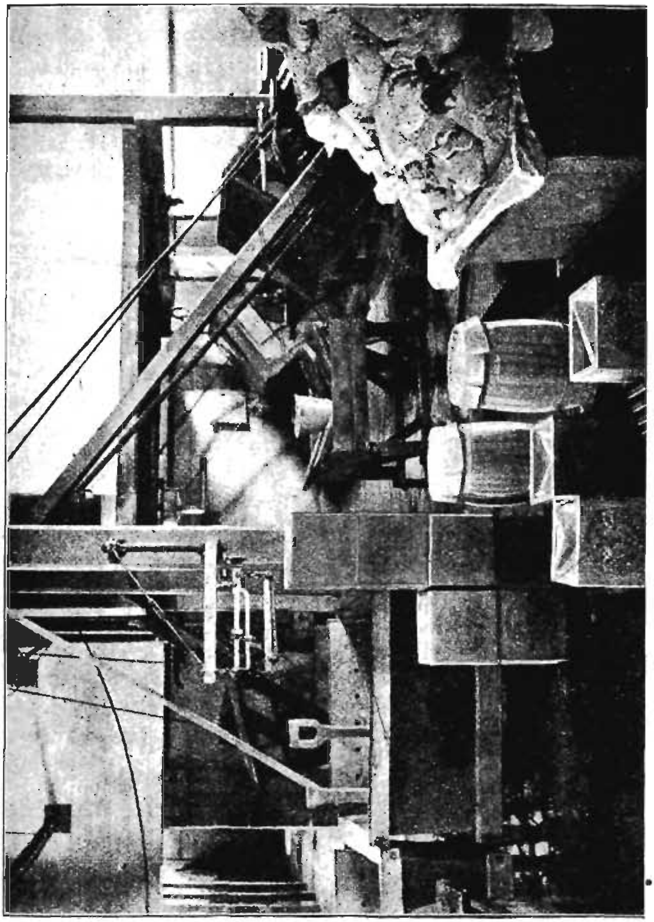

FIG. 42.—PART OF A BUTTER FACTORY. (By permission of the N.Z. Dept. of Agriculture.)

remove it to a table for salting and working. Wooden utensils should be used for moving the butter; never touch it with the hands.

Salting and Working. In most countries it is customary to add salt to the butter. The principal reason for this is that the salt improves the flavour, and so the use of salt depends entirely upon the market to which the butter is to be sent. Some countries demand a highly-salted butter, but in several parts of the world no salt at all is used. Butter for the British market should contain from 0·5 to 1 per cent. of salt. To get this result, it is necessary to use about ½ or ¾ of an ounce of salt to each pound of butter-fat. Salt is also generally thought to act as a preservative, and so a little more is used when the butter has to be kept for a long time. Many authorities, however, are very doubtful about the value of salt as a preservative, and hold that unsalted butter keeps its flavour better than the salted. A test was recently made with some lots of Australian butter after it had been stored for several months, and in every case the highest points for flavour were awarded to the unsalted butter. So, though it is usual, salting is not absolutely necessary. Working, however, is a part of the butter-making process which can never be omitted. The mass of fat which is left in the churn when the buttermilk is withdrawn is not butter, either in composition or texture; it contains a large quantity of milk-serum, and is a loose, wet mass quite different from the finished product. "Working" consists of pressing the butter, and it may be said to serve these purposes:

(1) It drives out the excess of buttermilk;
(2) It compresses the granules into a firm mass, and
(3) It works the salt evenly through the butter.

There are two main ways of salting: (1) brine-salting and (2) dry-salting. The first method is to make a fairly strong mixture of salt and water, and then, as soon as the wash-water is taken out, pour it into the churn, which should be revolved until the brine has thoroughly worked through the butter. The great advantage of this method is that the salt is evenly distributed through the butter, and so "mottles" are avoided.

Dry-salting, however, is the system generally followed. The butter is pressed out on the butter-worker or on a table, and a thin layer of fine salt is then sifted evenly over it. The butter must next be folded over and then pressed out again. Repeat this folding and pressing several times, and then put the butter on one side so that the salt may become thoroughly dissolved. This will require four or five hours at least, and the best way is to let it stand all night if possible. At the end of that time, the butter receives a second working in much the same way as before, except that it is better to *cut* the butter into strips instead of folding it. This lets the moisture get out more easily; folding keeps it in. The amount of working necessary depends upon the condition of the butter, but it must be continued until all superfluous water has been worked out and the salt is evenly incorporated all through the mass of butter. If there are drops of moisture and uneven patches of colour in the butter, it is a sure sign that the water has not been sufficiently worked out and the salt has not been thoroughly worked in. For salt heightens colour, and uneven colouring is nearly always caused by uneven salting. If the butter contains a large amount of

water before it is worked, a little more salt should be added, because much of it will be worked out with the water. The salt should be perfectly dry and should consist of very fine granules without any lumps. If the granules are too big, or if the salt is lumpy, it may be necessary to overwork the butter in order to get it thoroughly dissolved and worked in.

Over-working is always to be avoided, because it tends to destroy the individuality of the butter-granules and so make the butter greasy. The working should be done by means of a pressing motion, not a sliding one. A sliding motion makes the butter greasy.

The working is generally done by a piece of apparatus known as a "butter-worker," which is a table with a wooden roller attached. Many of the workers are circular, and the roller, which generally has fluted or flat sides, revolves round it.

Before use, the worker should be scalded with hot water and then thoroughly chilled again with cold; if this is neglected, the butter will stick to the wood and so spoil the working.

In up-to-date factories, the butter is worked in a modified churn, known as the "combined churn and worker." This method gives good, reliable results, and requires a much smaller amount of energy than the roller system of working.

If preservative is to be added to the butter, it should be worked in with the salt.

Cleaning the Churn. The churn must be attended to with the same regard to cleanliness as must all other dairy utensils. When not in use, it should be allowed to stand in a clean, dry place.

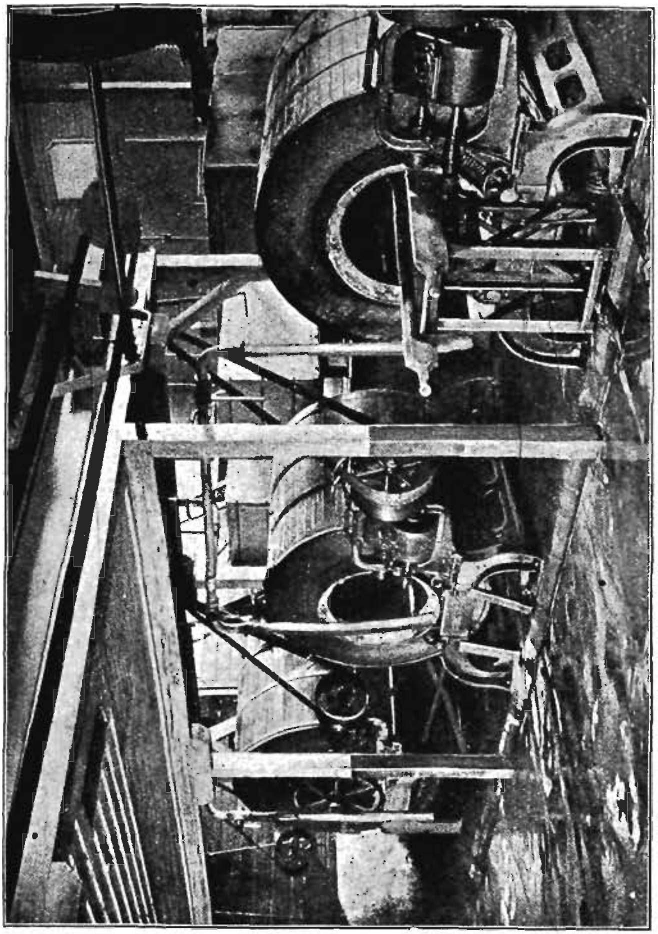

Fig. 43.—Combined Churns and Workers.

As soon as the churning is over, the churn should be washed out with slightly-warmed water in order to remove any remains of buttermilk. Then scour

it out thoroughly with boiling water and a little lime or soda; this washes away all dirt. Finally, rinse with pure, boiling water, and let it stand in the sun, if possible, until dry. The water heats the wood and soon evaporates on account of its own heat. A final rinsing with cold water cannot be recommended, because the wood will not dry properly when cold, and this very soon makes the churn become damp and musty.

Buttermilk. Buttermilk has much the same composition as ordinary skim-milk, and it can be used for feeding pigs and other farm animals in the same way as skim-milk can.

The amount of fat in buttermilk varies considerably, but it should not be more than 0·2 per cent. It is a good plan to test the buttermilk occasionally, so that, if it contains too much fat, steps can be taken to remedy the fault. Waste of butter-fat in this way can generally be prevented by proper attention to the churning.

QUESTIONS ON CHAPTER IX.

1. Give an account of pasteurized cream-ripening.

2. How does the stage of lactation affect churning, and why?

3. Explain briefly the process of butter-making from the time the cream is put into the churn until the finished butter is obtained.

4. What are the effects of (*a*) over-ripening, (*b*) over-churning, (*c*) over-washing, (*d*) over-working?

5. What is meant by "natural" ripening of cream? What are its disadvantages?

6. What are the temperatures (*a*) for churning, (*b*) for ripening the cream, (*c*) for washing? What is the effect of too high a temperature in each case?

CHAPTER X.

PROPERTIES OF BUTTER.

Composition of Butter. Butter contains the same substances as are found in milk, together with a certain quantity of salt. The salt and ash together form about 2 per cent. of butter, and 1 per cent. is made up of the proteids, casein and albumen. Unless made from unripened cream, the butter will also contain a quantity of lactic acid in place of some of the milk-sugar. Lactic acid and milk-sugar generally form from 0·5 to 0·75 of butter. Water is present to the extent of between 10 and 20 per cent. If the butter is to be of good quality, a certain proportion of water is necessary. It is very rarely, however, that we meet with butter containing too little moisture; excess of water is much more common. In most countries the law forbids the sale of butter containing more than a certain percentage of water—about 16 per cent. is generally the limit.

Excess of water is sometimes produced intentionally in order to increase the weight of the butter, but it is often entirely due to ignorance or insufficient care in the process of manufacture.

Causes of Excess of Water. (1) One of the objects of working butter is to squeeze out much of the water

which it contains. If not sufficiently worked, butter will always contain a large percentage of moisture.

(2) It is also important that the wash-water should be cold enough; warm wash-water is a frequent cause of excess of moisture.

(3) The use of too high a churning-temperature is inclined to have the same effect. When churned at a low temperature, the butter-granules are found to be of firm texture, and so they cannot be made to coalesce very readily. Consequently, prolonged churning is necessary, the effect of this being to make the granules compact and expel the moisture.

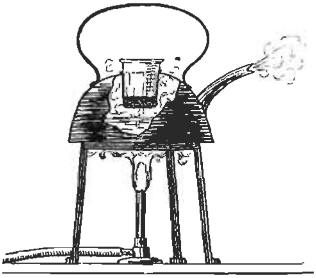

FIG. 44.—EVAPORATING THE MOISTURE FROM BUTTER BY MEANS OF AN ORDINARY KETTLE.

The Test for Moisture. The percentage of moisture in butter can easily be determined by weighing a sample, evaporating the moisture which it contains, and then finding the loss of weight. This represents the weight of water in the sample, and from it the percentage can easily be calculated. There are various methods of driving the moisture from the butter; we must choose some way of heating which will expel the moisture fairly quickly and yet not burn the solids.

A good method is to place the butter in a beaker over boiling water; charring of the solids is thus made impossible. Good results can also be obtained by heating the beaker of butter in a tin dish containing sand. As soon as all the moisture has passed off, the

heating should be stopped. To make sure that all the water has been evaporated, partly fill a small glass beaker with cold water, and wipe the bottom perfectly dry. Hold the beaker over the sample of butter. Any moisture still coming off will condense on the bottom of the beaker and be plainly visible; if the beaker still remains bright and clear, we may safely assume that all the moisture has been driven off. The amount of butter taken does not matter much, but it is difficult to get accurate results if the sample is too small. Twenty or thirty grams is a convenient quantity.

The following is the record of an average test:

Before Heating—

1. Weight of beaker empty - - 23·61 grm.
2. Weight of beaker and butter - 50 32 ,,
3. Weight of butter alone - - 26·71 ,,

After Heating—

4. Weight of beaker and butter - 46·45 ,,
5. Weight of butter alone - - 22·84 ,,
6. Weight of moisture in butter - = loss of weight $=(26{\cdot}71-22{\cdot}84)=3\ 87$ grm.
7. Percentage of moisture $=\frac{\text{wt. of moisture}\times 100}{\text{wt. of butter}}$

$$=\frac{3{\cdot}87\times 100}{26{\cdot}71}=14{\cdot}48 \text{ per cent.}$$

Butter-Fat. Fat forms the largest part of butter; the percentage varies according to the percentage of water, but it is generally between 80 and 86.

As already stated, butter-fat is not a simple substance, but is a mixture of nine or ten different fats. Unlike casein and albumen, fats contain no nitrogen, but, are all composed of the same three elements,

carbon, hydrogen, and oxygen. The different ways in which these elements are combined account for the various individual fats.

The fats found in butter are often called "glycerides" because they are compounds of glycerin with some acid. The characteristic fat of butter is butyrin, a compound of butyric acid and glycerin. Butyrin forms about 6 per cent. of butter. Rancid butter is caused by germs known as "butyric-acid bacteria." These are rod-like in shape and occur in strings. They split up the butyrin into the glycerin and butyric acid of which it is composed. The free butyric acid causes the disagreeable rancid taste and smell.

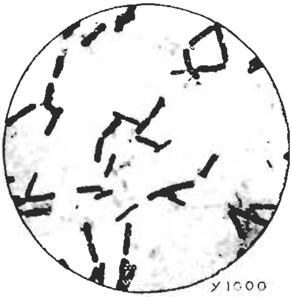

FIG. 45.—BUTYRIC-ACID BACTERIA. The cause of rancid butter.

Olein, a compound of oleic acid and glycerin, forms about 40 per cent. of butter. It is the softest fat in butter, being generally a liquid; olein solidifies at 42 degrees Fahr. Butyrin is also a soft fat.

Palmitin (palmitic acid and glycerin) and stearin (stearic acid and glycerin) are hard, white fats. Stearin melts at about 150 degrees Fahr. and palmitin a few degrees lower. These two fats together form about 45 per cent. of butter. Towards the end of the lactation period they increase, and make the butter-fat harder. On this account a higher churning-temperature should be employed towards the end of the season than at the beginning, because the fat-globules must be partly

melted before they will collect together and form butter-granules. The various acids (oleic, butyric, palmitic, stearic, myristic, caproic, etc.), which combine with glycerin to form glycerides or fats, are called "fatty acids."

Appearance of Butter. When cut across, butter should present an even yellow colour, and not contain any light or dark patches. Dark patches are generally due to improper working-in of the salt.

The addition of salt intensifies the colour of butter, and so uneven or "patchy" distribution of the salt through insufficient working will cause a mottled and streaky appearance.

Salt of uneven grain should never be used, because the larger pieces will remain undissolved at the conclusion of working and produce yellow specks in the butter. Streaks, mottles, and "specks" are defects which seriously injure the quality of butter.

In addition to the bright yellow patches caused by improper salting, we frequently find white streaks or specks in butter. These defects are also due to faulty methods.

If butter is not thoroughly washed, and consequently contains a considerable quantity of buttermilk, the latter will probably produce white streaks. Over-ripening of the cream has a similar effect. The acid which is produced coagulates more or less of the casein and causes it to be incorporated in the butter, instead of being left in the buttermilk. The particles of casein appear as white specks in the butter.

Texture. The word "texture" refers to the "grain" of the butter; this depends upon the condition of the

butter-granules and the way in which they have consolidated to form butter. Although closely pressed together, the granules should not lose their individuality and become merely a mass of fat. The more distinct the individual butter-granules are, the better the texture of the butter.

When broken across, a piece of butter should present a rough, broken appearance. Working too much, or at too high a temperature, tends to destroy the individuality of the butter-granules, and produce smooth greasy butter.

Overrun. People frequently wonder how it is possible for a dairy factory to pay a shilling a pound for butter-fat, and sell the finished butter at the same figure. In view of what has just been said about the composition of butter, this is very easily explained. Butter does not consist entirely of fat; about 15 per cent. of it is composed of very much cheaper substances, such as water, casein, and salt. With the exception of about 1 per cent. of salt, this portion of the butter costs the manufacturer nothing whatever. As a general rule 1 lb. of fat makes $1\frac{1}{6}$ lb. of butter. The extra one-sixth of a pound is commonly known as the "overrun." To be more exact, 100 lb. of fat should be sufficient to make 115 or 116 lb. of butter. It is the overrun that covers the cost of manufacture and slight loss of fat which occurs in skimming and churning.

Test for Salt in Butter. The quantity of salt in butter varies from 0·5 to 1 per cent. If the butter is to be kept for a long time, a little more salt is generally added as a preservative. There are various tests for determining the percentage of salt in butter, and they

all depend upon the use of silver nitrate solution, in much the same way as a solution of caustic soda is used to determine the acidity of milk.

A certain weight of butter is placed in a flask and shaken up with hot water; this dissolves the salt. The liquid is then allowed to cool, and when the fat has formed a layer on top, a definite quantity of the clear solution is taken from below with a pipette.

Some potassium chromate solution is added to this as an indicator. A solution of silver nitrate is then added carefully from a burette until a brick-red colour is obtained, and the number of cubic centimetres of solution used is ascertained by reading its level in the burette. As a rule, the quantities are so arranged that each cubic centimetre of silver nitrate solution used indicates 1 per cent. of salt in the sample of butter.

The following are details of a very convenient method:

Apparatus required. (1) Nitrate of silver solution, made by dissolving 5·1 grams of nitrate of silver in 250 c.c. of water; (2) potassium chromate indicator, made by dissolving an ounce of potassium chromate in 100 c.c. of distilled water, or rain water; (3) 10 grams of butter; (4) thermometer; (5) burette, graduated correctly to one-tenth or one-twentieth of a cubic centimetre; (6) a 17·6 c.c. pipette; (7) a wide-mouthed, stoppered bottle for holding the butter and hot water; (8) glass beaker; (9) an accurate balance; (10) graduated glass measure.

Method of Testing. (1) Weigh out exactly 10 grams of butter into a glass beaker. This is best done by putting the beaker into one pan of the balance, counterpoising with shot, adding a 10 gram weight to the shot, and then putting enough butter into the beaker to make the balance swing evenly again.

(2) With the graduated glass, measure out 250 c.c. of hot water (about 130 degrees Fahr.).

(3) Put the butter and the hot water into the wide-mouthed bottle, which should have a tight-fitting stopper. Any traces of butter which adhere to the beaker should be washed off with some of the hot water.

(4) Shake the contents of the bottle thoroughly, and allow them to settle. The fat will rise to the top, but the salt will remain dissolved in the water.

(5) By means of a pipette take 17·6 c.c. of the liquid below the fat layer, and put it into the beaker.

(6) Add two drops of the chromate indicator to the beaker, and mix by shaking.

(7) Add nitrate of silver solution, drop by drop, from a burette, until a permanent pale brick-red colour is obtained. The appearance of this colour denotes that all the salt has been neutralized.

(8) Find how many cubic centimetres of silver nitrate solution have been used. Each c.c. denotes 1 per cent. of salt. For instance, if 2·8 c.c. are used, the butter contains 2·8 per cent. of salt.

Butter Flavours. The best flavour which butter can possess resembles that of clean, well-ripened cream, free from all rancidity and unusual flavours. As in the case of milk, butter frequently possesses undesirable flavours due either to bacterial contamination or to the feeding of strongly-flavoured foods. In most cases, the cause of the trouble lies in the milk from which the butter was made.

1. The rancid flavour of butyric acid is due either to the staleness of the butter, or to old and over-ripened cream. Pasteurizing the cream, and re-inoculating it with a pure culture of lactic-acid germs, prevents rancidity, because it destroys the bacteria which produce the butyric acid.

2. Butter is sometimes said to possess a "cowy" odour. That is, it possesses a distinct animal taint, such as is found in the breath of the cow. Aeration will generally overcome this difficulty.

3. A "stable" flavour and odour is much more serious. It may be due to particles of dirt which have fallen into the milk during milking, or to impure gases which have been dissolved. These gases, chiefly ammonia, are given off by animal manure, and, being very soluble, speedily taint any milk which may be standing near. "Stable" flavours in butter can be prevented by cleanliness in milking, and removing the milk into a pure atmosphere as soon as possible.

4. Food flavours are due to the use of strongly-flavoured foods shortly before milking.

Cabbages, rape, turnips, and many other plants have this effect. By the taking of proper precautions, as explained in the chapter on the Care of Milk, these objectionable food flavours can be avoided.

QUESTIONS ON CHAPTER X.

1. What causes "excess moisture" in butter? Explain how you would determine the percentage of moisture in a sample of butter.

2. What are "rancid," "cowy," and "turnipy" flavours in butter? How may each be prevented or overcome?

3. Explain what "overrun" is, and how it occurs.

4. "Butter-fat consists of many fats." Explain this carefully.

5. What are the causes of yellow patches, white streaks, and white specks in butter?

6. Write a note on the texture of butter.

7. How would you find the percentage of salt in a sample of butter?

CHAPTER XI.

ACIDITY OF MILK.

THE term "acidity of milk" is used to denote the amount of acid which milk contains. The acidity of milk is due to two causes: first, to certain compounds of phosphoric acid known as acid phosphates, and, secondly, to the lactic acid which is made from milk-sugar by bacteria. The amount of the former of these acids, often called "the apparent acidity," is generally about 0·08 per cent. of the milk; it rarely exceeds 0·1 per cent. The total acidity of milk, however, is generally greater than 0·1 per cent., and the excess is due to the substance known as lactic acid.

Lactic Acid. This acid is peculiar to milk, as its name implies (Latin, *lac* = milk), and is produced by the fermentation of milk-sugar, which is brought about by certain minute organisms known as lactic-acid-producing bacteria. These bacteria enter the milk in various ways: numbers of them float about in the air wherever milk is kept, and may gain access to the milk either by settling on it in the cans or by entering the lower part of the cow's udder through the teats. The milk which is contained in the teats is always more or less contaminated by these germs even before milking,

but the milk in the udder itself is practically free from them. Unclean dairy utensils are another very common source of contamination. If the cans and pails are not thoroughly washed each time they are used, some of the milk will remain in the cracks or stick to the sides, and soon become the breeding-places of millions of bacteria, which are ready to attack the next lot of milk. After standing exposed to the air for some hours, the milk becomes sour to the taste; it then contains about 0·3 per cent. of lactic acid. The bacteria continue their attack on the milk-sugar, converting it into lactic acid, until the acidity of the milk has reached 0·9 per cent. Their action then ceases, as the presence of more than this amount of acid is harmful to the bacteria themselves; the milk is now said to have reached its "maximum acidity."

How to Test for Acidity. Everyone with the slightest knowledge of chemistry has heard of acids and alkalies. These are two very important classes, to one or other of which many of the commonest substances belong. Sulphuric acid, tartaric acid, nitric acid, vinegar (acetic acid), and lactic acid are all examples of acids. Caustic soda, caustic potash, ammonia, and lime are well-known alkalies. We can easily detect whether a substance is acid or alkaline by means of a piece of litmus paper. Take a red litmus paper and dip it into some "liquid ammonia"; it immediately becomes bright blue. If it is then placed in some acid liquid, such as sulphuric acid, it will become red again. So, in every chemical laboratory a stock of blue and red litmus papers is kept, to be used for discovering whether substances are acid or alkaline.

An acid turns a blue paper red; an alkali turns a red one blue.

Neutralization of Acids and Alkalies. Now, these two classes of substances are antagonistic, and counteract, or neutralize, each other. If a little liquid ammonia is mixed with sulphuric acid, the acid will immediately destroy or neutralize the alkaline properties of the ammonia, and at the same time, its own acidity will be lost. The sulphuric acid combines with the ammonia, and forms another substance which is neither an acid nor an alkali—sulphate of ammonia.

Such neutral substances, which are formed from the union of acids and alkalies, are called "salts." Common salt, carbonate of soda, and borax are all examples of salts.

"To neutralize an acid" means to add an alkaline substance to it until all its acidity has been used up by the alkali to form a salt; as soon as the acid ceases to turn blue litmus paper red, we know that it is no longer an acid, but has been neutralized by the alkali. If we add a little more of the alkali, the mixture will become alkaline and possess the power of changing the colour of red litmus to blue. It is by this method of neutralization that we are able to determine how much lactic acid is present in a sample of milk. We know, for instance, that a certain amount of alkaline liquid is necessary to neutralize 0·1 per cent. of lactic acid. If, then, we find that five times this amount is required before a particular sample of milk ceases to be acid, we may infer that the milk contains 0·5 per cent. of lactic acid; if only twice the amount of alkali is needed, then the milk is only 0·2 per cent. sour, and so on.

The Indicator. In this test for acidity, we use not litmus papers, but a substance called "phenolphthalein," to indicate whether the milk is acid or alkaline. Phenolphthalein gives a very delicate test. While the milk is acid there is no difference in its appearance, but as soon as it becomes slightly alkaline, the colour changes from white to pink. If more alkali is added, the pink will turn to a bright red. Litmus, you will remember, was red for acid, and blue for alkalies; phenolphthalein, a much more delicate indicator, is colourless for acids, and red for alkalies. The indicator is prepared by dissolving 10 grams of phenolphthalein in 250 c.c. of alcohol.

The Alkali Solution. In order to find how much acid there is in a sample of milk, we must have an alkali solution of known strength, with which to neutralize that acid. What is known as a "standard solution" of caustic soda is generally used. It is prepared by dissolving 4 grams of pure caustic soda in a litre of distilled water. This seems very simple, but the greatest possible care must be exercised to see that the exact quantities of caustic soda and water are taken, and that both are quite pure. Ordinary commercial caustic soda is not pure. The solution should be kept in a glass-stoppered bottle, and protected from the air, or it will gradually become weakened through the absorption of moisture and carbonic acid gas.

Operating the Test. Having our alkaline solution, phenolphthalein, and sample of milk all ready, we still require a 17·6 c.c. pipette for measuring out the milk, a burette for the alkali, and a glass flask or white cup

to hold the milk during testing. The small conical-shaped flask shown in the illustration (Fig. 46) serves the purpose very well, as it allows the operator to shake up the contents thoroughly without much danger of

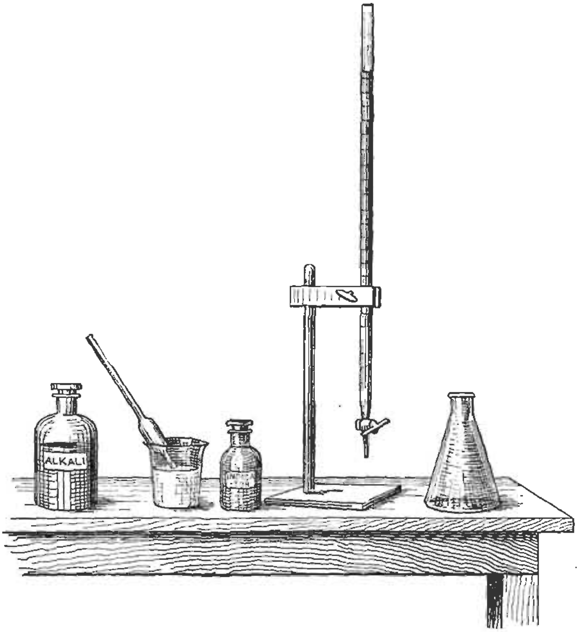

FIG. 46.—APPARATUS USED IN THE ALKALINE TEST FOR ACIDITY.

spilling them. If a burette is not obtainable, a glass flask graduated in cubic centimetres can be used instead.

Fill the burette to the 0 mark with alkali solution, and mix the sample of milk thoroughly. Take 17·6 c.c. of milk with the pipette, and put it into the cup or glass flask. This quantity of milk weighs exactly

18 grams. Add four or five drops of phenolphthalein solution. The next step is to neutralize the lactic acid in the milk with the caustic soda solution. Let a little of the solution run into the milk, and mix thoroughly by shaking. Add a little more and shake again. Continue to do this until the mixture of milk and alkali assumes an even pale pink colour, which it still keeps after thorough shaking. This colour indicates that all the acid has been neutralized and that the milk is just slightly alkaline. If allowed to stand, it would lose the pink colour in time, owing to the formation of more lactic acid. The caustic soda solution neutralizes the acid, but does not destroy the bacteria themselves; it rather encourages them. Now look and see how much alkaline solution has been used. Let us suppose, for the sake of example, that 8·5 cubic centimetres of it have been taken from the burette in order to neutralize the acidity of the milk.

Now each cubic centimetre of standard alkaline solution neutralizes 0·009 of a gram of lactic acid, and so, to determine the amount of acid in the milk, we multiply 0·009 by the number of grams of solution used. In this case we find that the 18 grams of milk contained $0{\cdot}009 \times 8{\cdot}5 = 0{\cdot}0765$ of a gram of lactic acid. In order to determine the percentage of acidity, divide this by the number of grams of milk used, and multiply the result by 100. It works out to 0·425 per cent. of lactic acid. Either more or less than 18 grams of milk may be used for this test, but that is a convenient quantity to handle.

The number of cubic centimetres of solution used must be multiplied by 0·009, divided by the number of cubic centimetres of milk, and then multiplied by 100, to get the percentage of acidity. The whole thing may be expressed by the following formula:

Percentage of acidity

$$= \frac{0{\cdot}009 \times \text{c.c. of alkali solution}}{\text{c.c. of milk}} \times \frac{100}{1}.$$

As each lot of caustic soda solution is added to the milk, a tinge of red will be noticed. This, however, disappears when the flask is shaken, and the alkali combines with the lactic acid to form a salt known as sodium lactate. When once a permanent pink tinge has been obtained, no more solution must be added. If the milk contains more alkali than the lactic acid can neutralize, the phenolphthalein will cause it to become bright pink.

In this case the result will not be accurate, and the test should be done again with another 18 grams of the milk.

Acidity of Cream. The test just described is simple enough to be used by any dairyman for finding the acidity of cream previous to churning. As a rule, cream properly ripened for churning should contain from 0·5 to 0·6 per cent. of acid. If the acidity exceeds 0·6 per cent., it may possibly cause the casein to coagulate into small lumps and appear as mottles in the butter. The correct degree of acidity for churning, however, depends a good deal upon the percentage of fat which the cream contains. It is found that, to obtain the best churning, a rich cream requires to be less acid than a thin one ; the smaller the percentage of fat, the greater the acidity required. For instance, cream with 20 per cent. fat should contain as much as 0·72 per cent. of acid in order to give the best results ; a 30 per cent. cream requires 0·63 per cent. of acid ; and the acidity of a 40 per cent. cream need not exceed 0·54 per cent.

Farrington's Tablet Test. This test is another method of finding the percentage of acid in milk. It is based on exactly the same principles as the one described in the preceding paragraphs, but it possesses

some features which make it more convenient, and also lessen the chance of getting an inaccurate result. The alkaline-tablet test avoids the trouble of making and keeping a standard solution, as the alkali is supplied in the form of small compressed tablets, each of which also contains a small quantity of phenolphthalein. The chief advantages of the tablets over a standard alkaline solution are that they keep without loss of strength for a lengthy period of time, and can easily be made into a solution by anyone who exercises a little care, whereas a standard solution cannot be relied upon unless it has been prepared by a chemist or some properly-qualified operator. The test is performed in the following way :

A glass cylinder, graduated in cubic centimetres, is filled with water up to the 97 c.c. mark, and five of the tablets are dropped in. The cylinder is then tightly corked and laid down on its side for two or three hours until the tablets are completely dissolved ; they dissolve more quickly with the cylinder in this position than when it is standing upright. Then thoroughly mix the milk or cream to be tested, and draw out 17·6 c.c. of it by means of an ordinary Babcock pipette. Run it into a glass flask or clean white cup, and rinse out the pipette once, adding the rinsing water to the cream in the flask or cup. There is no need to add phenolphthalein, as this is already contained in the tablets. Now proceed to neutralize the acidity of the milk with the alkaline solution in the usual way.

Pour a few cubic centimetres of solution from the cylinder into the cream, and mix thoroughly by shaking round or stirring with a spoon. Continue to add small quantities of alkali ; as soon as the pink colour ceases to disappear readily, add only a few drops at a time until a permanent pale pink colour is obtained. A

little practice will be necessary before you are able to perform this test neatly.

Then look at the glass cylinder and find how many cubic centimetres of alkaline solution have been used. Each c.c. represents 0·01 per cent. of acid in the cream, so multiply the number of c.c. of solution used by 0·01, and the result is the percentage of acid in the sample of cream.

For instance, suppose there are 54 c.c. of solution left in the cylinder at the conclusion of the test. Subtracting this from 97 c.c. we find that 43 c.c. have been used to neutralize the acidity of the cream. The percentage of acid, therefore, is $43 \times 0{\cdot}01$, or 0·43 per cent.

QUESTIONS ON CHAPTER XI.

1. Explain the meaning of (*a*) acid, (*b*) alkali, (*c*) a salt, (*d*) indicator.

2. Say how you would prepare solutions of alkali and phenolphthalein for the acidity test.

3. Explain carefully how you would find the percentage of acid in a sample of milk.

4. Upon what conditions does the ripeness of cream required for churning depend ?

5. What advantages are derived from the use of alkaline tablets instead of a standard solution ?

6. What is meant by the "apparent acidity" of milk ?

CHAPTER XII.

STARTERS AND THEIR PREPARATION.

WHAT a starter is has already been briefly explained in connection with the subject of cream-ripening. Starters may be prepared in two ways—either by the natural ripening of pure milk, or by inoculating milk with a scientifically-prepared "culture" of lactic-acid bacteria.

A Natural Starter. A natural starter is derived from the fermentation of milk in the ordinary natural way, without the addition of any artificially-prepared bacteria. A quantity of milk is taken and kept at about 65 or 70 degrees Fahr., this being the best temperature for lactic-acid fermentation without the growth of harmful germs as well. The selection of the milk is very important; only the cleanest and best-flavoured milk should be used. A good lactic-acid fermentation produces a smooth, even curd with a clean, pleasant flavour. The appearance of gas in the curdled milk is considered to indicate the presence of putrefactive bacteria, and such milk is not fit to be used as a starter. The best method is to allow several samples of milk to sour and curdle. The one which produces the best curd should then be chosen and

"built up" into a starter by the method soon to be described.

The great disadvantage of a "natural" starter, as of natural cream-ripening, is the uncertainty of getting a good result. "Commercial" starters are much more reliable, and have now almost entirely superseded the "natural" system.

Preparation of a Commercial Starter. A commercial starter is made by adding lactic-acid bacteria to milk, and then keeping the milk for a certain length of time at the temperature best suited for the development of the bacteria. The bacteria are supplied in the form of a "pure culture." This is a preparation of milk, beef-broth, gelatine, or some other nutritive substance in which lactic-acid bacteria have been allowed to grow. Before the culture is added, the milk selected for the starter should be pasteurized, in order to kill all bacterial life. This can be done by keeping the milk at 160 degrees Fahr. for 30 minutes and then cooling to about 70 degrees as soon as possible. The starter has then to be "built up."

The process of building up a starter consists of three or four stages.

1st Stage. After the milk has been pasteurized, it must be inoculated with the culture and allowed to ripen. Not much milk is required for this purpose at first; about a pint is usually ample. Information as to the exact quantities of milk and of culture to be used is generally supplied with the bottle of culture. During ripening, the milk should be kept at a temperature between 70 and 75 degrees Fahr., and the quantity of culture should be sufficient to bring the milk to the

proper degree of ripeness in about twenty-four hours. When ripened, the milk should be evenly thick and contain from 0·6 to 0·65 per cent. of lactic acid. It is important to notice that, although lactic-acid bacteria develop best at about 100 degrees Fahr., the temperature of the starter must be kept between 70 and 75 degrees during ripening. This is because even the pasteurized milk is not absolutely pure, but contains undestroyed spores and also bacteria which have entered after pasteurization. The lactic-acid germs can compete with these best at about 70 degrees Fahr. At high temperatures stale flavours and gassy fermentations are frequently developed, and it is difficult to avoid over-ripening. Too low a ripening-temperature is liable to cause bitter and other undesirable flavours. It also prolongs the time required for ripening, and so gives harmful germs a good chance of developing and contaminating the starter.

This, then, is the first stage in building up a starter; we add the pure culture to a small quantity of pasteurized milk and keep it at 70 degrees Fahr. for about twenty-four hours, at the end of which time the milk should be from 0·6 to 0·65 per cent. sour.

2nd Stage. The ripened milk can now be used as a starter to inoculate a larger quantity of milk. The latter, of course, must first be pasteurized and guarded from subsequent contamination. The quantity of starter added should be about 2 per cent. of the milk; it should then be allowed to stand for about twenty-four hours at 70 degrees. At the end of that time it will have become ripened, in the same manner as the first starter.

3rd Stage. This second quantity of ripened milk is itself used to ripen a third and larger quantity in practically the same way as a starter is used to ripen cream for butter-making. For the third propagation a lower ripening-temperature (between 60 and 65 degrees) is employed.

Pasteurized milk is inoculated with 2 per cent. of its bulk of starter, as before, and then kept at between 60 and 65 degrees Fahr. for twenty-four hours. By the end of that time it should have formed into a fairly firm curd and contain about 0·85 per cent. of lactic acid.

The starter has now been " built up " ; it is ready to be used for inoculating cream in the manner shortly to be described.

"Carrying on" a Starter. We have just seen how a starter is built up. It is not necessary to go through this process every time a starter is used, because, once built up, a starter can be " carried on " or " kept going " for a month. A sufficient quantity of starter should be made each day for adding to the cream and also for inoculating a fresh starter. This inoculation of pasteurized milk each day by some of that day's starter is known as " carrying on " a starter. Before a ripe starter is used, either for ripening cream or for inoculating a fresh starter, the top portion should be skimmed off to the depth of one inch. The top of the starter always has a poorer flavour than the deeper portion ; this is most probably due to contamination by germs from the air or to harmful fungoid growths, such as oidium lactis, upon the surface. If the top portion is added to cream with the rest of the starter,

it will not seriously affect the result, but it should never be used to propagate a new starter. By taking such precautions we can prevent undesirable bacteria from developing and being carried on day by day in the starter. For the purpose of inoculating a quantity of milk, about 2 per cent. of starter should be added ; the milk should be kept at a ripening-temperature of 70 degrees Fahr. for twenty-four hours, at the end of which time it should be fit for ripening cream and also for inoculating the next day's starter. As a starter may become bad suddenly, it should always be examined before use. If it shows signs of bad flavours, a starter is not worth carrying on ; it will do more harm than good. To provide for such an emergency as this, it is a good plan to put a quantity of reliable starter into a cold room where it can be kept for a week or so. It will retain its good qualities and, should the main starter become unfit for use, can be built up into a new starter in a much shorter time than would be required for building one up from a commercial culture.

Changing a Starter. As a rule, a starter should not be " kept going " for more than a month ; starters are frequently kept too long. No matter how much care is taken to prevent contamination, a starter must become more or less " dirty " in that time. A new starter should then be built up from the pure culture ; it will generally be more vigorous and better flavoured than the old one.

Using the Starter. Now that we understand how a starter is built up and carried on, let us consider the method of using it in the manufacture of butter or cheese. A starter is in the best condition for use when

it contains the greatest possible number of lactic-acid bacteria. This occurs about the time it coagulates; the milk may then contain as many as 2,000,000,000 bacteria per cubic centimetre, its acidity being about 0·85 per cent. The starter should not be kept at ripening-temperature for long after it coagulates, or over-ripening will probably take place. Over-ripening is undesirable, not because a little more lactic acid would harm the starter, but because the lactic-acid bacteria make very slow progress after 0·85 per cent. of acidity is reached; meanwhile, the harmful germs develop rapidly and cause bad flavours. This applies especially to the butyric-acid bacteria, which flourish in a plentiful supply of lactic acid, causing rancid and "fishy" flavours in the butter. If a starter cannot be used as soon as it is properly ripe (0·85 per cent. of lactic acid), it should be cooled to as low a temperature as possible. The starter should be passed through a strainer when it is put into the vat; this breaks up any curds, which would otherwise tend to sink to the bottom of the vat. The quantity of starter used for cream-ripening varies greatly. Many considerations must be taken into account, such as the time the ripening is to occupy, the condition of the cream, and the flavour desired.

The Best Medium. Whole milk is not the only medium used for the propagation of starters. Sometimes part of the buttermilk from the churning or some of the ripened cream is used as the next day's starter. Some operators prefer skim-milk to whole milk, but it is doubtful whether one is better than the other. Whatever the medium may be, the most important thing is that it should be selected and

ripened with the greatest attention to cleanliness. Experiments have also been made with artificial mediums, to see if something cheaper than milk will do as well.

A solution of milk-sugar, inoculated with a pure culture of lactic-acid bacteria, has been found to give fairly good results. Glucose solutions, properly ripened, produced as good a flavour in the butter as ordinary milk starters, but the cream required twice or thrice the time for ripening.

QUESTIONS ON CHAPTER XII.

1. What is a "pure culture" of lactic acid?
2. What is meant by "carrying on" a starter? How is it done?
3. Explain how you would build up a starter from a pure culture.
4. Why is a starter not ripened at the temperature most favourable to the development of lactic-acid germs?
5. Explain how a "natural" starter is built up. Why is it inferior to a "commercial" starter?
6. Give directions for using a starter in cream-ripening.

CHAPTER XIII.

HERD-TESTING.

EVERYTHING which helps to increase the size of the monthly cheque is of importance to the dairy-farmer. If he is a factory-supplier and is paid for the butter-fat which his milk contains, he will use every available means of making the yield of fat from his herd as large as possible. Not only should he pay attention to the health and proper feeding of his stock, but he should take care that his herd contains no cows whose yield of milk does not pay for their keep and leave a fair profit as well.

The poultry farmer will not keep unprofitable fowls; the orchardist cuts down the trees which do not bear; neither should the dairy-farmer allow unprofitable cows to remain in his herd. How is he to tell which animals are profitable and which are not? It is not safe to judge a cow by the quantity of milk she gives, because very often a cow whose milk-yield is comparatively small will produce more butter-fat than any other animal in the herd. It is quite possible for a cow which gives only 6000 pounds of milk in a year to produce more butter-fat than one whose yield of milk exceeds 9000 pounds. Neither should the colour of the milk be relied on too much as an indication of its fat-content, because the colour is often very deceptive.

We must ascertain the amount of fat in the milk by means of some scientific and accurate method, such as the Babcock test. That is the only sure way of finding which cows are worth keeping and which are not. But merely to know the fat-percentage is not enough. The size of the factory-supplier's cheque depends on the *number of pounds* of fat he has sent in during the month, and not upon the *percentage* of fat in the milk. Consequently, the value of a dairy cow depends upon these two things taken together—the fat-percentage and the quantity of milk.

The farmer who wishes to increase his income by weeding out all unprofitable animals should keep regular records of the weight of milk and its fat-percentage yielded by each cow, all through her period of lactation. The weight of milk is easily found by hanging it in a bucket on a spring balance, and the fat-percentage can be determined by means of the Babcock test. The ideal way, of course, would be to take these records at each milking, but that would mean a very large amount of work.

The following method, which is much simpler and almost as accurate, is the one usually followed.

The cow's milking period is marked off into periods of thirty days in each. On two successive days in each of these periods records are taken of the milkings of each cow. Although no records are taken on the other twenty-eight days, this method gives results from which the year's yield of milk and butter-fat can be calculated quite accurately enough for ordinary purposes.

On the morning and evening of each of the two days selected for making the test, the milk should be weighed

as soon as it comes from the cow. The best way to do this is to hang the bucket of milk on a spring balance and then to subtract the weight of the bucket from the total weight. This is done each morning and evening, and the four results so obtained are entered opposite the cow's name or number upon a sheet of paper. At the same time, four samples of the milk are taken and put into a bottle with a little preservative. One of these bottles is needed for each cow. A four-ounce bottle is of convenient size.

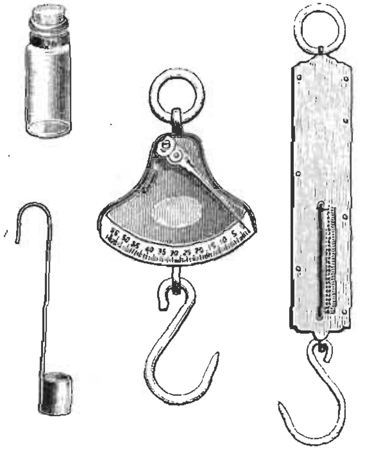

FIG. 47.—TYPES OF SCALES, SAMPLE-BOTTLE AND SAMPLE-DIPPER SUITABLE FOR COW-TESTING. (From *N.Z. Agric. Dept. Journal.*)

The sampling can be done with a small dipper fixed to a long wire handle. The milk must be thoroughly mixed by pouring to and fro several times before the sample is taken.

It is also important to see that the same quantity of milk is taken each time, and that the samples are all put into the right bottle. When the four samples of milk have been taken and put into the bottle, the mixture is tested for fat-percentage.

The result of the test gives the average percentage of fat in the four milkings, and this is also entered upon the record-sheet. Having the fat-test and the number of pounds of milk given in the two days, we can easily calculate the weight of butter-fat. Then, by multiplying

this by 15, we obtain approximately the yield for the whole thirty days. If this is repeated every period of thirty days, the total for the year can be obtained. Then the farmer should consider which animals are worth keeping and which are fit only to be sent to the sale-yard or to be fattened for the butcher. No cow which gives less than 200 lb. of butter-fat in the year can be considered profitable, and the farmer should be able, by carefully culling out the "robbers," to raise the average yield of his herd to at least 250 or 300 pounds.

A bulletin of the Iowa Experiment Station (U.S.A.) states that, of several thousands of cows tested, one in every three failed to pay for her keep. In many a herd much of the profit from the few good cows is used to feed the "robbers."

The records of a test conducted by the Illinois Experiment Station show that the twenty-five best cows tested yielded as much as the 1020 worst.

The year's records of a herd of ten cows are shown below. Three of these cows, "Cary," "Lottie," and "Spot," were afterwards culled out.

Name.	Pounds Milk.	Average Test.	Pounds Fat.
Cary - -	3846	4·07	156·5
Maggie - -	7086	4·25	300·4
Daisy - -	8398	3·4	285·5
Lottie - -	4965	3·41	169·3
Spot - -	4907	3·72	182·9
Tabby - -	6406	3·82	244·6
Granny - -	7625	3·57	272·4
Beeky - -	6429	3·41	219·3
Billy - -	7000	3·73	261·3

Herd-Testing Associations. In many places dairy-farmers have formed Herd-Testing Associations. The members themselves take the samples and record the weight of milk. Then they send the sample-bottles and record-sheets in a box to the Association's testing station, which is generally the nearest creamery. There the samples are tested for fat-percentage by a properly-qualified operator, who enters the results upon the record-sheets and returns them, together with the empty bottles, to their owners. A record-sheet is here shown properly filled up.

COW-TESTING FORM

Springdale Association Herd No. 6

Name: J Smith Address: Springdale

Dates of Weighings: 23rd and 24th March 1914

No.	Name of Cow	Age	Last Calf	Weighing Morn. (Lb)	Weighing Even. (Lb)	Test	Lb. Fat
1	Spotty	5	Sep.3	22 / 22	21 / 20	3·9	3·315
2	Freckle	8	Aug18	18 / 18	17 / 17	3·6	2·52
3	Bijou	6	Oct.12	22 / 22	21 / 21	4·7	4·042
4	Brownie	5	Nov.2	24 / 24	23 / 23	3·5	3·29
5	Daisy	7	Oct.9	16 / 16	14 / 15	5·0	3·05
6	Milly	9	Oct.6	15 / 15	15 / 14	3·4	2·06
7	Alice	4	July4	15 / 16	14 / 14	3·8	2·242

FIG. 48.—THE RECORDS OF TWO DAYS' MILKINGS.

QUESTIONS ON CHAPTER XIII.

1. What is the value of herd-testing ?

2. A farmer wishes to cull unprofitable cows from his herd. Explain carefully the best method for him to adopt.

3. What is a " Herd-Testing Association " ?

CHAPTER XIV.

PRESERVATIVES.

MILK is often adulterated by the addition of (1) water or skim-milk, (2) some chemical preservative.

Water, it will be remembered, lowers the specific gravity of milk, and the addition of skim-milk raises it, so we can discover, by means of the lactometer, whether milk has been watered or skimmed. This has been fully explained in Chapter II.

Watering and skimming are wrong, because they are means of cheating the persons who buy the milk, but the addition of chemical preservatives is to be condemned for even stronger reasons. Some of them are very poisonous, and all are injurious to health when present in fairly large quantities. Another strong objection to preservatives is that they are used to disguise dirty methods. The careless dairyman well knows that his dirty milking-shed and unscalded cans are the breeding-places of billions of harmful bacteria, which will enter the milk and cause it to go bad more quickly than it ought. So he tries to conceal these insanitary conditions by adding some chemical substance which will either destroy the germs or delay their action, because the rapid souring of milk is a sure indication of insanitary methods.

Clean milk needs no preservative. For this reason, it is illegal to sell milk containing any preservative whatever. The preservative substances most commonly used are bichromate of potash, formalin, borax, and bicarbonate of soda.

Bichromate of Potash. This substance is rarely used to adulterate milk intended for human consumption, because it is easily detected by its bright orange colour. It is commonly used in dairy factories, however, to preserve samples of milk till testing-day; this, of course, is quite legal. Bichromate of potash is a salt, being a compound of chromic acid and potash. For use as a preservative it is generally sold in the form of small tablets, one tablet being sufficient to preserve about half a pint of milk.

Bichromate of potash is very poisonous. The bright orange colour of this substance makes its presence so very evident that it is hardly necessary to use a chemical test to detect it.

Formalin. The preparation known as "formalin" is a clear, colourless liquid made by dissolving the gas formaldehyde in water. Ordinary formalin contains 40 per cent. of formaldehyde gas. Formalin is the strongest germ-killer known. A single drop of it is sufficient to keep half a pint of milk from souring for a week. Formalin, however, must never be used to preserve milk which is intended for food, because it is poisonous, and a very small quantity of it is sufficient to injure the consumer's health. Being in liquid form, formalin is more convenient than bichromate of potash for preserving samples of milk, but it is apt to harden the solids and make them difficult to dissolve.

For this reason the smallest possible quantity should be used.

The Test for Formalin. We can easily discover whether milk contains formalin or not by proceeding as follows.

Pour a small quantity of the milk into a test-tube, and add an equal quantity of water. Mix well by shaking the tube. Then pour down the side of the tube a little strong sulphuric acid (the same as is used for the Babcock test). The acid, being heavy, falls to the bottom of the tube. Wait a few moments for it to settle and then, if formalin has been added to the milk, a bluish-violet ring will appear at the place where milk and acid meet. This violet ring is a sure sign of formalin. The test is very delicate, and can detect the slightest traces of formalin. It is said that if there is only one part of formalin in 200,000 parts of milk, the bluish-violet ring will appear.

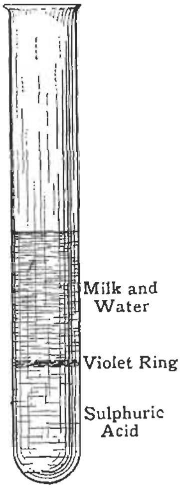

FIG. 49.—THE TEST FOR FORMALIN IN MILK.

Borax and Boracic Acid. Borax and boracic acid (also known as "boric" acid) are frequently used to preserve dairy products. Borax, or sodium borate, is a compound of boric acid and soda. Both borax and boric acid can be detected by the same test. The test is easily made, although it is not so simple as the test for formalin.

Take a small quantity of the suspected milk (about 10 or 15 cubic centimetres will be sufficient). Make the milk alkaline by adding a little lime-water or

caustic soda solution. Then evaporate the milk until only the solids are left. Place the dry solids in a small porcelain crucible, and heat strongly until all the combustible substances have been burnt off. When the ash which remains has cooled down, pour a little weak hydrochloric acid upon it Take a strip of turmeric paper, dip it into the liquid, and then heat the paper gently until it is dry. If the milk is pure, the colour of the paper will remain unchanged. If it contains borax or boracic acid, the colour will change from yellow to dark-red. In order to make the test still more certain, dip the reddened paper into some caustic soda solution, and the colour will change to dark green.

Turmeric paper, like litmus paper and phenolphthalein, is used for discovering whether a substance is acid or alkaline. It is yellow in colour, remains unchanged by acids, but is turned brown by alkalies. Turmeric paper can be obtained from any chemist. Borax is not a dangerous poison, and its use in small quantities for preserving dairy products is sometimes permitted by law.

Boric acid compounds form the principal constituent of butter preservatives.

Borax and boracic acid can also be detected by the use of sulphuric acid and alcohol. Take about 10 c.c. of the suspected milk in a crucible, and evaporate it to dryness. Then burn the solids gently, and add four drops of sulphuric acid and a little alcohol or methylated spirits. Set fire to the liquid. If borax is present, the alcohol will burn with a flame tinged bright green at the edges.

Bicarbonate of Soda. Sometimes bicarbonate of soda, or "baking soda," is used to preserve milk. It

is not a disinfectant, as formalin and boric acid are, and does not injure the bacteria. On the other hand, bicarbonate of soda rather encourages the action of the lactic-acid-forming bacteria.

Bicarbonate of soda is a salt, but a salt in which only half the alkali (soda) has been neutralized by the acid (carbonic acid). Consequently it is still alkaline, and, when put into milk, combines with the lactic acid, preventing it from souring the milk. The bacteria themselves are not hindered by the bicarbonate of soda ; the removal of the free acid allows them to make more acid so long as the supply of milk-sugar lasts. In order to test for bicarbonate of soda, pour a small quantity of the milk into a dish and reduce it to ash by heating strongly. Bicarbonate of soda is not combustible, and any which may have been in the milk will remain in the ash. Allow the ash to cool, and then pour some hydrochloric acid upon it. If bicarbonate of soda is present, it will cause the acid to effervesce.

Detecting Preservatives. If milk is suspected to contain preservatives, examine it in the following way :

(1) Note the colour ; an unnatural orange tint is a sign of bichromate of potash.

(2) Test for formalin.

(3) Reduce some of the milk to ash, and divide the ash into two parts.

(4) Test one part of the ash for bicarbonate of soda.

(5) Test the other part for borax.

QUESTIONS ON CHAPTER XIV.

1. Why is the addition of chemical preservatives to milk forbidden by law ?

2. What is formalin ? How may it be detected ?

3. Why does bicarbonate of soda prevent milk from souring ? Compare its action with that of formalin.

4. A sample of milk is suspected to contain borax. How would you test it ?

CHAPTER XV.

CHEESE-MAKING.

THE object in cheese-making is to separate the casein and fat from the other constituents of milk, and compress them into a compact mass known as cheese. This separation is brought about by the use of rennet, which precipitates the casein; that is, the rennet causes the minute particles of casein which are suspended in the milk to unite together, forming a thick curd. The fat-globules are caught in the precipitated casein and become incorporated in the curd. The watery liquid which remains is known as "whey." The curd is afterwards chopped, heated, and pressed into moulds. To obtain the best results, it is necessary to use milk of the best quality only, clean, sweet and of good flavour. The manager of a cheese factory should always refuse inferior milk, as its use may seriously injure the whole output of cheese, and cause loss to those patrons who supply nothing but first-quality milk.

There are two main classes of cheese—cheddar cheese and soft cheese. Cheddar cheese is distinguished from soft cheese by the fact that it is made from curd which has been allowed to tighten or "cheddar"

into a firm mass. Soft cheese is made from loose curd, and is not so common as the cheddar variety.

Cheddar Cheese-making. On arriving at the cheese factory, the milk should be examined by a qualified person to see that it is sweet and clean-flavoured ; none but first-quality milk should be accepted. The milk is then run into a large vat made of wood or metal with a smooth bottom sloping towards one end. About a pound of cheese can be made from each gallon of milk. A quantity of starter is added in order to produce the desired flavour.

Ripening. The preparation of a starter has already been fully described. A method commonly used may be briefly stated as follows :

Take 15 lb. of fresh milk, and pasteurize it by heating at 195 degrees Fahr. for twenty minutes. Allow the milk to cool to 90 degrees, and add a small bottle of pure culture of lactic-acid bacteria. Keep the milk at about 90 degrees all day so that it may ripen thoroughly. The next day add to it 15 lb. more of pasteurized milk, and stir it thoroughly. The temperature of this added milk should be about 80 degrees. On the third day the ripened milk can be used for propagating the final starter for use in cheese-making. The final starter is made by adding 8 ounces of it to 200 lb. of milk. After standing for a day, this starter should be added to the milk in the ripening-vat. Between 1 and 1½ lb. of starter should be used for every 100 lb. of milk, the exact quantity being left to the cheese-maker's own judgment. Great care must be taken to protect the starter from all contaminating influences, so that it may be " carried on " from day to day without deteriorating in quality.

After the starter has been stirred into the vat, the milk should be allowed to stand until the correct

degree of acidity is obtained. To encourage the ripening process, the temperature of the milk is raised to 85 degrees Fahr.; this can be done by means of steam in factories, or by placing cans of hot water in the vat and stirring occasionally.

Renneting. The acidity of the milk should be tested at intervals; when the milk contains 0·2 per cent. of lactic acid the rennet should be added. The acidity of the milk can be determined either by the alkaline test or by the rennet test (described later). Rennet is a preparation made from the lining of the fourth stomach of the calf. It contains various ferments which coagulate the milk; they act best at a temperature between 85 and 90 degrees Fahr. The lactic-acid starter also helps to coagulate the milk, but its chief purpose is to improve the flavour of the cheese. From 3 to 5 ounces of rennet should be used for every 1000 lb. of milk, or a teaspoonful for every 25 lb. It should be dissolved in a small quantity of cold water, and then stirred into the vat for several minutes. If colouring matter is to be used, it should be dissolved in about a pint of milk and put into the vat before the rennet is added; the usual quantity is a teaspoonful of cheese-colour for every 10 gallons of milk.

Curdling. After the addition of the rennet the milk should be allowed to stand for about twenty minutes to coagulate. When the curd will break clean and retain its shape, like a firm custard, it is ready to be cut.

Cutting. The curd is cut into small cubes by means of special curd-knives. These are rectangular in shape, and consist of a large number of blades.

The best method is to use the knife with the horizontal blades first, cutting along the length of the vat. Next cut across the vat with the vertical knife and then *along it. In this way the* curd is cut into small regular cubes.

The cutting should be done fairly quickly, but not carelessly; careless cutting causes loss both in quality and in quantity of the cheese. After cutting, the curd should be stirred slowly for ten or fifteen minutes.

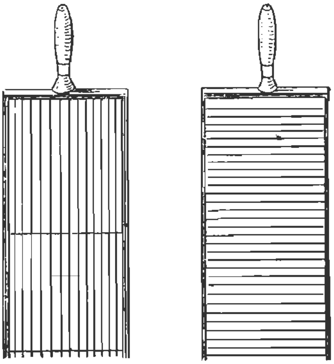
FIG. 50.—CURD-KNIVES.

Cooking. The curd must next be "cooked." This is done by gradually raising the temperature to about 100 degrees Fahr. and stirring the curd occasionally to prevent it from matting. Thirty-five or forty minutes should be occupied in reaching the desired temperature. The question of temperature must be carefully attended to, and is best left to the cheese-maker's own judgment. Sometimes it is sufficient to heat up to 97 degrees, and sometimes a temperature of 102 degrees is necessary. The effect of "cooking" is to consolidate the curd and expel the whey.

Dipping. The curd should be allowed to remain in the vat until about three hours have passed since the rennet was added. The whey should then be tested for acidity, and when it contains about 0·2 per cent. of acid it should be run off through a tap. If the

vat is not provided with a tap, the curd can be strained by means of a large colander.

Cheddaring or Matting. The curd should then be piled into heaps on a rack or at one side of the vat, and allowed to stand for fifteen minutes, so that all the whey may drain out. During this time the curd will "cheddar," or mat together, into a solid mass. It should next be cut into strips about 2 ft. long and 1 ft. in depth and breadth. These strips should be turned over at intervals of ten minutes for two hours. The whey which drains out should be tested for acidity and, when it shows 0·7 or 0·8 per cent., the curd is ready for milling.

Milling. The curd is milled by being passed through a machine which chops it into small pieces something like potato chips. The milled curd should be allowed to ripen further for about an hour, being well stirred every few minutes.

Salting. The salt should be added when the whey from the curd shows an acidity of 1 per cent. It should be allowed to dissolve thoroughly and be well distributed through the curd by stirring. At this stage, the temperature of the curd should be about 82 degrees. The exact quantity of salt to be used depends upon many considerations; one ounce of salt to every 25 lb. of milk is generally considered sufficient. The salt hardens the curd, improves the flavour, and checks the production of lactic acid.

Pressing. The cheese-hoop, generally made of tin, should be round, strong, and have straight sides. A circular piece of wood called the "follower" should exactly fit in the top. There are various ways of pressing the curd into "cheeses."

One method is to line the sides of the hoop with cheese-cloth, fill it with curd, and press for about three-quarters of an hour. At the end of that time the cheese is removed from the hoop and "dressed." The bandage of cheese-cloth is moistened with hot water, pulled smooth, and turned over neatly at the ends. Circles of cheese-cloth are placed on the ends

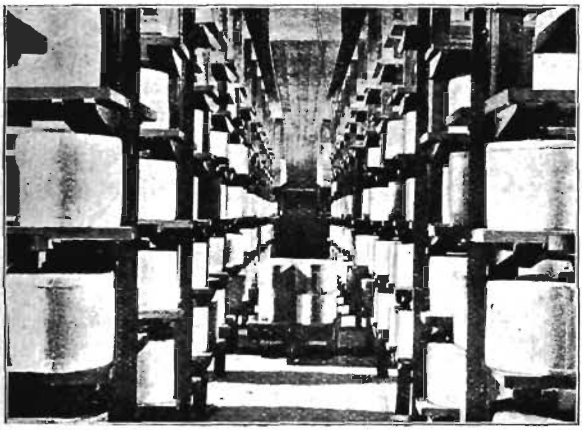

FIG. 51.—CHEESES IN COLD-CURING CHAMBER.
(By permission of N.Z. Dept. of Agriculture.)

of the cheese, which is then put back into the hoop and kept under pressure all night.

Curing. Next day, the cheeses are removed from the hoops and placed upon shelves in the curing-room, where they remain for three or four months. During this time certain changes take place in the cheese which improve its flavour, and also make it more digestible.

The temperature of the curing-room is generally

kept at between 65 and 70 degrees ; too high a temperature is likely to cause the fat to run out of the cheeses.

Nowadays the system of "cold-curing" (at about 50 degrees Fahr.) is gradually replacing the old method. It causes less loss of weight by evaporation of moisture and is said to produce a better quality of cheese.

During the process of curing, the cheeses should be turned daily to prevent loss of shape.

The Rennet Test. This is a very convenient test for determining whether the milk is sufficiently acid to have the rennet added. A dilute solution of rennet is made by mixing a small quantity of rennet extract with nine times as much water. 5 c.c. of this dilute solution should be added to 140 c.c. of milk from the vat, and thoroughly mixed with it by stirring. The rennet will cause the milk to coagulate rapidly, and the time required for coagulation indicates the acidity of the milk. If the milk coagulates completely in about fifty seconds from the time the rennet solution was added, the rennet should be put into the vat. If more than sixty seconds are occupied before the milk will coagulate, it is not sufficiently ripe for renneting ; coagulation in less than forty seconds denotes over-ripeness, in which case the milk requires special handling.

Summary of Operations in Cheddar Cheese-making:

1. The milk is put into a vat.
2. The starter is added.
3. The milk is heated to 85 degrees Fahr.
4. The milk is stirred occasionally during the ripening to prevent cream from forming on the top.

5. When the milk shows 0·2 per cent. of acid, or curdles by the rennet test in about 50 seconds, the rennet is added.
6. The milk stands for about 20 minutes to curdle.
7. The curd is cut into small cubes.
8. The curd is "cooked" by gradually heating during 35 minutes to about 100 degrees Fahr.
9. The whey is allowed to run out of the vat when it contains 0·2 per cent. of acid.
10. The curd is piled into heaps and allowed to cheddar for 15 minutes.
11. The curd is cut into strips.
12. The strips are turned at intervals of 10 minutes for 2 hours.
13. When the whey contains 0·7 or 0·8 per cent. of acid, the curd is milled.
14. The milled curd is allowed to ripen for an hour at about 82 degrees Fahr.
15. Salt is added and worked in.
16. The curd is put into a cheese-hoop and pressed for an hour.
17. It is taken out and "dressed."
18. The cheese is replaced in the hoop and pressed for about 20 hours.
19. Next day it is placed on a shelf in the curing room, and, unless intended for export to a distant market, is kept there for 3 or 4 months.

The Composition of Cheese. Cheese contains about one-half of the solids which were originally in the milk.

This includes almost all the fat and casein, but the milk-sugar, albumen, and most of the ash remain dissolved in the whey. Cheese may be made from whole milk, skim-milk, cream, or a mixture of any of these, and its fat-content varies accordingly. When cheese is made from whole milk, as is generally the case, the percentage of fat always exceeds that of casein, and the percentage of water is about the same as that of fat.

An average sample of cheddar cheese should contain about 36 per cent. of fat, a similar quantity of water, 25 per cent. of casein, and 4 or 5 per cent. of the other milk-solids.

After cheese has been kept for a time it will be found to have lost some of its weight, owing to the evaporation of part of its moisture. As a rule, about 3 per cent of the total weight is lost in this way. Many cheese-makers, especially in Canada, prevent shrinkage by coating the cheeses with a thin layer of paraffin wax. In one case, 22,000 cheeses which had been treated in this way, were cold-cured (at 50 degrees) for several months, and the total loss of weight was only 43 lb. The cost of the wax is about one penny per cheese.

Cheese Colouring. The colouring matter most commonly used in the manufacture of cheese is annatto. This is a preparation made from the reddish-yellow pulp which covers the seeds of the annatto plant. In the West Indies and tropical America, where annatto is principally grown, the natives collect the seeds and place them in shallow pans. There they are frequently turned until dried by the strong sun. The colouring matter is then dissolved from the surface

of the seeds, and is used in the manufacture of butter, cheese, confectionery, and varnishes.

Certain aniline dyes, which are prepared from tar, are also used as colouring matter instead of annatto. Some of them, however, are poisonous, and several countries, including Denmark, absolutely prohibit their use in the manufacture of butter and cheese.

Soft Cheese-making. Cheddar cheese obtains its name from the village of Cheddar, in the south-west of England, where the process was first employed hundreds of years ago. The distinguishing feature of cheddar cheese-making is the matting or cheddaring of the curd, which consolidates it and helps to expel the moisture. In the manufacture of "soft" cheeses, the curd is not allowed to cheddar, the object being to keep it soft and wet. There are many different varieties of soft cheeses, the best known being Gervais, Camembert, Double Cream, Little Welsh, and Coulommier.

Soft cheeses ripen very rapidly, and will not keep for any length of time, so that it is necessary to have a ready market for them.

Gervais Cheese. This variety of soft cheese is made from a mixture of new milk and cream, in the proportion of two parts of milk to one of cream.

The milk and cream should be thoroughly mixed by stirring them together, and then warmed to about 70 degrees Fahr. Rennet, at the rate of 1 c.c. to every 12 lb., is then diluted with cold water and added to the mixture. The addition of a little clean starter is also advisable, but not absolutely necessary. The time required to coagulate the mixture of milk and cream depends upon the temperature and upon the

quantities of rennet and starter added. If a starter is used and the mixture is kept at 70 degrees Fahr., coagulation should take place in eight hours. If no starter is added and a lower temperature, say 65 degrees, is employed, eleven or twelve hours will be required. The curd should then be ladled out with a dipper and placed in a cloth. The cloth should be made into a bag by tying the four corners together with string, and be hung up to drain. After the curd has been draining for some time, the flow of whey will become blocked by the hardening of the curd on the outside. When this happens, open out the cloth and scrape it to remove the hardened curd. Then mix the scrapings with the soft curd in the centre. This should be done at intervals of two or three hours, the time required to drain the curd depending greatly upon the frequency with which the cloth is scraped. When the curd is sufficiently firm, it should be turned into a basin and salted, at the rate of 1 ounce of salt to every 3 lb. of curd. The salt, which should be fine dairy salt, must be well worked into the curd. Small moulds about 2 inches in diameter and 2½ inches high, are lined with thin, white blotting-paper, and filled with the curd, which should be pressed down tightly, by means of a spoon. The cheeses can then be shaken out of the moulds. Like all soft cheeses, Gervais cheese does not keep for long, and should be eaten within a week, although some people prefer it a few days older. If kept at a sufficiently low temperature, it may, of course, be stored for an indefinite length of time; too high a temperature, on the other hand, will cause it to become over-ripe in less than a week.

Little Welsh Cheese. Little Welsh is one of the most popular varieties of soft cheese. It is much larger than Gervais, each cheese weighing about 1½ lb. To make cheeses of this size, a gallon and a half of sweet milk should be taken for each cheese required, and placed in a vat. The temperature having been brought to about 85 degrees Fahr., rennet should then be added, at the rate of fifteen drops to each gallon of milk. After about an hour, the milk should be sufficiently curdled. The curd may be tested in the usual way by breaking it with the finger; if it breaks "clean," leaving sharp edges, it is ready for cutting. The next process is to cut the curd into small pieces with curd-knives, in the manner described earlier in this chapter, after which it should be allowed to stand for five or six minutes. The curd should then be stirred with the hands for about half an hour, care being taken that none is left sticking to the sides or bottom of the vat. After the stirring, the curd should be allowed to settle for about ten minutes, and then ladled out to drain; this is best done by putting it on to a wooden rack over which a clean cloth has been spread. The curd will require fifteen minutes for draining, by the end of which time the small pieces will have united into a soft mass again. It should then be cut into blocks about 6 inches square, and turned two or three times during the next quarter of an hour. The blocks of curd should then be broken up with the hands and mixed thoroughly with salt, which may be added at the rate of 7 ounces to 20 lb. of curd. The best dairy salt is necessary; it should be soft, and free from lumps or grittiness. After the salt has

been thoroughly worked in, the curd should be packed loosely into moulds, which may be placed upon finely-grooved boards to enable the moisture to drain away easily. When the curd has settled in the mould for some minutes, it should be turned over so that both ends of the cheese may be smooth. The cheeses should be turned several times during the next two days, and then be removed from the moulds. Strong bandages of calico should be wrapped round the cheeses, and renewed daily for two or three days, until the surface of the cheese has become dry. After ripening for about three weeks the cheeses may be sold ; during ripening they must be turned daily.

Coulommier Cheese. Coulommier is a thin, round cheese, measuring 5½ inches in diameter and about 1½ inches in thickness. A gallon of milk is sufficient to make two cheeses, each weighing about a pound when fresh ; the weight decreases as the cheeses become older, owing to evaporation of moisture. To make Coulommier, sweet new milk should be poured into a vat, allowing half a gallon for each cheese required, and be brought to a temperature between 80 and 85 degrees Fahr. Rennet, at the rate of six drops to each gallon of milk, should be diluted with water and stirred thoroughly into the milk in the vat. The milk should then be allowed to stand for ten minutes, at the end of which it should receive a stirring, especially near the surface, in order to prevent the fat from rising to the top. Three such stirrings, at intervals of ten minutes, will be required. But, as soon as coagulation has commenced, the stirrings must be discontinued ; otherwise, a large proportion of

fat will be lost in the whey. At the end of the first half-hour, then, the milk receives its last stirring. It should now be covered with a cloth in order to retain the heat, and allowed to stand for two and a half hours. At the end of that time a fairly firm curd will have formed, but it may still require another half-hour's standing. When the curd can be broken cleanly with the finger, it is ready to be put into the moulds.

The Coulommier mould consists of two rings of tinned steel, about 5½ inches in diameter. One of the rings, known as the "collar," fits on top of the other, the two together forming a mould 5 inches high. Having fitted the moulds together, place them on straw mats on draining-boards, where they can remain undisturbed for some time. Then carefully ladle the curd into them until they are quite full. The cheeses should be allowed to drain for about ten hours, until the top of the curd has sunk to the lower edge of the "collar," which is almost half-way down the mould. Then remove the collars, place a straw mat and a board on the top of each cheese, and turn it over. Carefully remove the straw mat which was at the bottom, and sprinkle ¼ ounce of dairy salt over the end of the cheese. Allow the cheese to stand twenty-four hours; then turn it, remove the other mat, and sprinkle on ¼ ounce of salt in the same way as before.

For the next four or five days, turn the cheeses twice daily. By the end of that time they will be sufficiently firm to retain their shape, so they may be taken from their moulds and sold. If desired fresh, Coulommier may be eaten as soon as it is removed from the moulds. Many people, however, prefer it ripened. The ripening

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may be done by keeping the cheeses for a few days in a well-ventilated room to dry them, and then removing them to the ripening-room, where they remain on shelves for two or three weeks.

QUESTIONS ON CHAPTER XV.

1. What is the difference between cheddar cheese and soft cheese ?

2. What is the use of the rennet test ? Describe carefully how you would perform the test.

3. Outline briefly the successive steps in the manufacture of cheddar cheese.

4. Say what you know about the composition of cheese.

5. What are the objects of salting and curing cheese ?

6. By what means can cheeses be prevented from losing weight ?

7. How is Gervais cheese made ?

CHAPTER XVI.

USE OF DAIRY BY-PRODUCTS.

THE annual cost of keeping a dairy cow varies in different parts of the world, according to the cost of land, feed, and labour. A butter cow repays about one-third of the cost of her keep by the two important by-products, skim-milk and manure. A cheese cow produces the same value of manure, but the whey is worth only half as much as skim-milk. According to the *Journal* of the New Zealand Department of Agriculture, the total cost of keeping a dairy cow for one year in that country is £12 18s. 6d. A butter cow returns £4 16s. 0d. of this sum in skim-milk, calf, and manure.

Skim-milk - - -	£2	0	0
Calf - - - - -	0	6	0
Manure - - - -	2	10	0

Whey having only half the feeding value of skim-milk, the by-products of a cheese cow are worth about £1 less than those of a butter cow.

Whey - - - -	£1	0	0
Calf - - - - -	0	6	0
Manure - - - -	2	10	0

The above figures are for New Zealand only, and do not hold good for all countries. As an example,

however, they show clearly the importance of dairy by-products.

Skim-milk. Skim-milk is an excellent food for pigs of all ages, having a very considerable influence in the production of firm bacon. It may be fed to well-grown pigs either sweet or sour, but is better for young animals when sweet.

FIG. 52.—A FACTORY-SUPPLIER'S CART.
Showing tank underneath for skim-milk or whey.

Skim-milk and whey should be pasteurized at the dairy factory before they are returned to the farm for feeding purposes. This destroys tuberculosis germs, and prevents the spread of the disease to young calves and pigs. For human beings also, skim-milk is a valuable food. Although most of the fat has been taken from it, the body-building elements still remain. Being rich in protein, skim-milk is a valuable food for

all growing animals. It is strongly recommended for poultry, especially for young chickens.

Skim-milk is an excellent cheap food for calves instead of whole milk. It will not make them grow so quickly as whole milk, but, on the other hand, costs less than one-quarter as much. The saving effected by using skim-milk is much greater in value than the increase of weight which could be obtained by the use of whole milk.

The composition of skim-milk varies considerably; it is very poor in butter-fat, but rich in milk-sugar and proteids. The composition of an average sample of separator skim-milk is shown in the following table:

Water - - - -	90·7 per cent.
Fat - - - -	0·05 ,,
Sugar - - -	4·9 ,,
Casein - - - -	3·0 ,,
Albumen - - -	0·6 ,,
Ash - - - -	0·75 ,,

Buttermilk. Buttermilk is the liquid which remains in the churn after the butter has been removed. The percentage of fat in buttermilk depends largely upon the conditions under which the cream was churned.

Except when diluted by the addition of wash-water to the churn, buttermilk very closely resembles skim-milk in composition. An average sample of buttermilk should consist of the following substances:

Water - - - -	90·7 per cent
Fat - - - -	0·2 ,,
Sugar - - -	4·6 ,,
Casein - - - -	3·1 ,,
Albumen - - -	0·6 ,,
Ash - - - -	0·8 ,,

About 0·5 of the 4·6 per cent. of lactose is present in the form of lactic acid. Buttermilk, when not diluted with water, has practically the same feeding value as sour skim-milk, and is suitable for the same purposes.

Whey. Whey is the liquid portion of the milk which remains after removal of the curd in cheese-

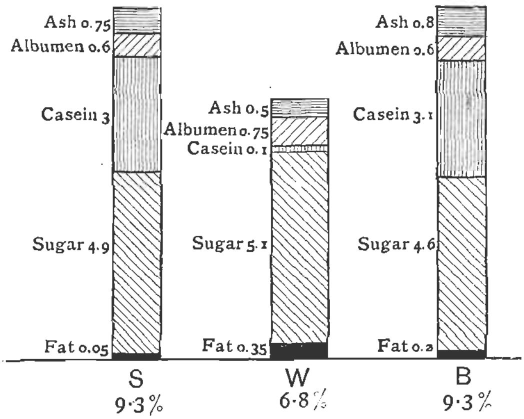


FIG. 53.—THE COMPOSITION OF THE SOLIDS IN SKIM-MILK (S), WHEY (W) AND BUTTERMILK (B).

making. The greater part of the fat and casein is incorporated in the curd. The albumen, which is not precipitated by rennet, and the soluble ingredients are left in the whey. Whey is used as a food for animals in the same way as skim-milk and buttermilk, but has only about half their feeding value, owing to the low percentage of fat and proteids. Whey generally contains between 0·3 and 0·4 per cent. of fat. The greater part of this can be taken out by

the separator and made into butter known as "whey butter." A factory producing 100 tons of cheese can make 2 tons of butter from the fat which remains in the whey.

The "skim-whey" which remains is still suitable for feeding to young animals, but its feeding value is diminished about 25 per cent. Whey is also the principal source of lactose, which constitutes 5 per cent. of it by weight. Lactose in the pure form is largely used for medicinal and other purposes; it can conveniently be obtained from whey by removing the other solids and evaporating the water.

The average composition of whey is shown in the following table:

Water	93·2 per cent.
Fat	0·35 ,,
Casein	0·1 ,,
Albumen	0·75 ,,
Sugar	5·1 ,,
Ash	0 5 ,,

Manure. Although the fact is not generally recognized, the most valuable by-product of a dairy farm is the manure. In one year an average cow produces about 10 tons of manure, in which form the greater part of the plant food eaten is returned to the soil. Cow manure does not contain so much plant food as horse manure, but is more lasting in its effect, probably because its higher percentage of water causes it to ferment more slowly.

A ton of cow manure contains about 10 lb. of nitrogen, 3½ lb. of phosphoric acid, and 9 lb. of potash. These are the substances specially valuable

as plant foods. The quantities present in cow manure make it worth five or six shillings a ton. An average cow produces 10 tons in a year, and so we may safely assume the annual value of manure from each cow to be £2 10s. 0d.

Animal manure is the oldest, and still the most popular of fertilizers. Before it can be used by plants as food, manure must be decomposed into various soluble substances. This is done by various kinds of putrefactive bacteria. It is best to give heavy clay soils fresh manure and let it rot in the ground; this helps to make the soil more open. Loose, sandy soils, however, benefit by the application of well-rotted manure. For this purpose the manure should be allowed to remain in a heap upon a concrete floor for some time before use. The concrete floor should be made sloping towards one corner, beneath which a bucket should be placed to catch any liquid manure flowing from the heap. The liquid can then be poured over the heap again or used in the garden. A manure heap should never be allowed to get too hot, because this causes the escape of ammonia gas; ammonia contains nitrogen, and is a valuable plant food. Overheating is due to too vigorous bacterial activity. It can be prevented by keeping the manure fairly wet, as this consolidates the heap and deprives the bacteria of air. The addition of gypsum (sulphate of lime) to the heap is to be recommended, as it "fixes" the ammonia; that is, it combines with it and so prevents the escape of this valuable substance in the form of gas.

QUESTIONS ON CHAPTER XVI.

1. Compare the feeding values of skim-milk, buttermilk, and whey.

2. For what purposes can skim-milk be used? Compare its feeding value with that of whole milk.

3. State the average composition of whey, and of butter-milk.

4. Say what you know about the value of the manure produced on a dairy farm.

5. For what purposes can whey be used?

CHAPTER XVII.

PHYSIOLOGY OF THE COW.

The Bones. The body of the cow is built upon a framework of bones. These are very numerous, and we cannot consider them all, but we must just notice the several groups into which they may be divided. First of all, there is the **skull**, which forms the framework of the head and protects the brain. It consists of several bones, which are fixed together tightly, and, with the exception of the lower jaw, are not movable. The skull rests on the end of a long chain of bones known as the "vertebral column" or "backbone." This is made up of a number of small, irregularly-shaped bones called "vertebrae." Each vertebra has a hole through it, and these holes form a long tube running the whole length of the backbone. Within this tube is the spinal cord, a thick bundle of nerves, which lead from the brain, and branch out into every part of the animal's body. Nerves are like so many telegraph wires, stretching from every bone, blood-vessel and muscle to the brain, which corresponds to the central office. If a cow leans against a barbed-wire fence, one or more of the barbs will pierce the skin and irritate a nerve. The nerve immediately carries the

message to the brain, where it is felt as a sensation of pain. The brain then sends out messages by other nerves to the muscles of the legs, commanding them to act in a certain definite way, and the result is that the animal's body is moved away from the barbed wire. Nerves, then, are like telegraph wires, their function being to carry messages between the brain and other parts of the body.

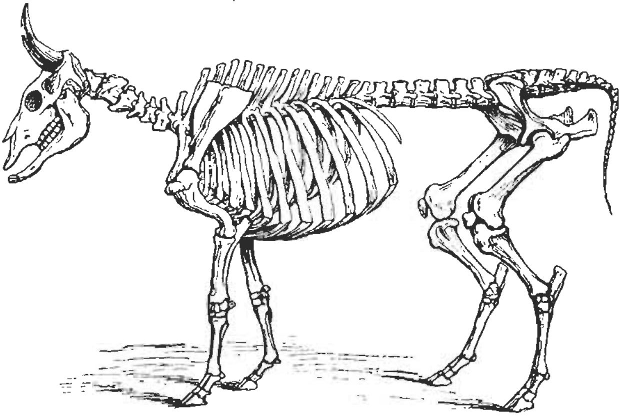


FIG. 54.- SKELETON OF A COW.

The **ribs** are long, thin bones, each of which is more or less semicircular in shape. They are arranged in opposite pairs, forming the framework of the chest. Each rib is attached to a vertebra at the back, and joins the sternum, or breast-bone, underneath the chest, thus forming a complete circle. There are thirteen pairs of ribs in the cow altogether, but only eight of these are joined to the breast-bone. The other five pairs, known as "false ribs," do not meet the breast-bone; they are attached to the vertebrae,

however, and are held together at the lower end by a tough material called "cartilage." Beneath the tail end of the vertebral column is the **pelvis**. This is shaped like a large basin, and consists of several bones tightly fixed together. The milking qualities of a cow depend considerably upon the size of the pelvis, as a large pelvis gives breadth to the hindquarters, and allows ample room for the udder to expand.

The Hind Limbs. There are two cup-shaped hollows in the pelvis, one at each side, and into these hollows the two thigh-bones fit. The thigh-bone, or femur, is the topmost bone in the hind limbs; at its lower end is the stifle-joint, where it meets another long bone, the tibia; at the lower end of the tibia is a very complicated joint, known as the hock-joint; below this is another long bone, the metacarpal, which meets with the pastern bone, forming the fetlock-joint. Below this joint is a number of small bones, and then, finally, the hoof.

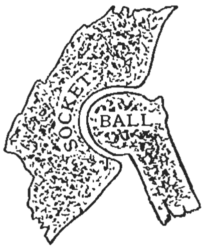


FIG. 55.—SECTION THROUGH A BALL-AND-SOCKET JOINT.

All these bones can be clearly seen in the illustration of a cow's skeleton (Fig. 54).

The Fore Limbs. The bones of the fore legs are arranged on very much the same plan as those just described. Corresponding to the thigh-bone is the "upper arm-bone." At its upper end is a round knob which fits into a cup-shaped hollow in a large triangular bone called the shoulder-blade.

This type of joint, known as a "ball-and-socket joint," occurs in several parts of the cow's body, but

the shoulder and hip joints are the most important examples of it.

The lower end of the upper arm-bone is jointed with two smaller bones lying side by side—the elbow-bone or ulna, and the radius-bone. The joint made by these bones is known as the elbow-joint. Below the ulna and radius is the knee, a very complicated joint, which contains six small bones as well as the ulna and radius above and the shank below. The shank-bone corresponds to the metacarpal bone of the hind limbs. The remaining bones are just the same as in the hind leg, viz. the fetlock-joint, several small bones arranged in pairs, and the hoof.

The foregoing is only a very brief survey of the skeleton of a cow. Many things have been omitted, but enough has been said to give us just a general idea of the bone framework upon which the animal's body is built.

The Internal Organs. Within this framework of bones are the heart, liver, stomach, and other internal organs. They are divided into two groups by a sheet of muscle called "the diaphragm," which stretches right across the body near the hindmost ribs. The part in front of the diaphragm is called the "thorax," and the part behind, the "abdomen." In the thorax are the lungs and heart, whose respective functions are to purify the blood and to pump it through blood-vessels all over the body.

The abdomen contains chiefly those organs which are concerned with the digestion of food and the passing of the indigestible parts out of the body, viz. the stomach, liver, intestines, spleen, kidneys, and bladder.

Running through all these organs is an immense number of nerves and blood-vessels. The blood-vessels are long tubes of varying size which carry the blood from one part of the body to another, and so keep all the organs and limbs supplied with nourishment. Over the whole is stretched a tough, pliable covering, the skin. Underneath the cow's body, part of this skin hangs down to form a bag—the udder. In this organ the milk is made, and so the udder is of the greatest importance to the dairy farmer. As is to be expected, a cow's milking qualities depend considerably upon the form and size of her udder.

Circulation of the Blood. As we have already noticed, there is a stream of blood always flowing through every part of a living body, whether it be the body of an animal or of a human being. The blood-stream is the means by which the various organs and limbs are supplied with nourishment, and waste products are carried away. If a limb were bound very tightly, so as to shut off the blood supply completely, it would soon become useless and decay. The circulation of the blood is controlled by the great organs of the thorax— the heart and the lungs.

The heart is really a pump, and has large blood-vessels opening into it. One brings blood to the heart; another carries it away. As soon as it is filled with blood from the first of these vessels, the walls of the heart contract and force the blood out through the other. This alternate filling and emptying of the heart is always going on, a supply of blood continually arriving and being forced out again.

How is it that the blood does not run back into the

same blood-vessels by which it entered the heart? This is prevented by a wonderful arrangement of valves in the heart, which allow the blood to flow one way only. Those blood-vessels which convey blood *to* the heart are called "veins"; and those which convey it *from* the heart, "arteries."

Veins can be seen just under the skin in many parts of the body; the arteries lie further in, but we can easily feel them swelling and contracting regularly as each beat of the heart sends a fresh lot of blood along them. When the doctor feels a patient's pulse, he is really noticing the beating of an artery which lies in the wrist; the frequency and the strength of the beats tell him how the heart is doing its work. The artery by which the blood leaves the heart is very large in diameter, but it soon branches, and the branches themselves branch and re-branch, gradually growing finer and finer, until there is just a network of minute tubes called "capillaries." These capillaries soon link up again, however, forming small veins, which finally become united into the one large vein which returns the blood to the heart.

We must now consider the work which the lungs perform in connection with the circulation of the blood.

When the blood first leaves the heart, it passes through an artery into the lungs, through which it is thoroughly dispersed by means of the capillaries just described. It then undergoes a very important change. Air, when it is breathed into the lungs, contains a very important gas called oxygen, without which animals cannot live. The blood is sent to the lungs in order that it may be refreshed with a supply of oxygen, and so

made fit to keep up the health of the body. If, for any reason, such as impure air or an obstruction in the windpipe, the animal cannot get a supply of oxygen, its blood will become impure and useless. At the same time as it is revived by a supply of oxygen, the blood is cleansed of the impurities which it has collected. These are breathed out in the form of a gas, known as carbon dioxide. It is for this reason that ventilation is so important; air which has once been breathed

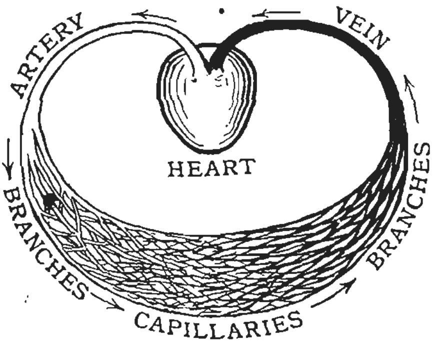


FIG. 56.—DIAGRAMMATIC VIEW OF THE CIRCULATION.

should not be taken into the lungs again, because it is deficient in oxygen and contains a large quantity of carbon dioxide.

Having passed through the capillaries of the lungs, the purified blood is gathered together and conveyed to the heart again. It is then forced out through a large artery, and so reaches every part of the animal's body.

The whole process is then repeated. That is, the blood flows back to the heart, is driven into the lungs and there purified, returns to the heart, and is again pumped through the body.

Physiology of Nutrition. The cow requires regular food for three main purposes—to build up the body, to supply energy and heat, and to provide those substances from which milk is made.

In the cow's body grass and other fodders are transferred from the vegetable kingdom to the animal. But before this can be done, the vegetable foods must be digested; that is, they must be broken up into a number of simpler substances, some of which are again combined together to build up the animal's body. This work is done chiefly by the organs of the abdomen. A continuous series of organs, resembling a long tube, stretches from one end of the animal to the other. Commencing with the mouth, it passes through the thorax as a tube called the "gullet," and, on entering the abdomen, is enlarged to form four bag-like structures, the stomachs. A tube known as the small intestine leads out of one of the stomachs, and is followed by a wider and larger tube, the large intestine. The intestines are many feet in length, and occupy a large part of the abdomen. The whole series of organs is called the alimentary canal (*alimentum* = food). In this canal the food is digested; that is, it is changed into a form which is suitable for the nourishment of the animal.

In the mouth itself certain juices are produced which commence to act upon the food, but it is in the fourth stomach and the intestines that almost all the work of digestion is done. The chewing, or mastication, which the food receives in the mouth, however, is important, because the food is thereby chopped and ground into small pieces which can easily be digested by the juices in the alimentary canal.

On leaving the mouth, the food is forced through the gullet by a peculiar peristaltic, or worm-like, motion, until it reaches the first of the four stomachs.

This is a large bag, called the **paunch** or **rumen**. It is easily the largest of the stomachs, and has a capacity of about forty gallons. Very little, if any, of the food is digested in the paunch. The organ is

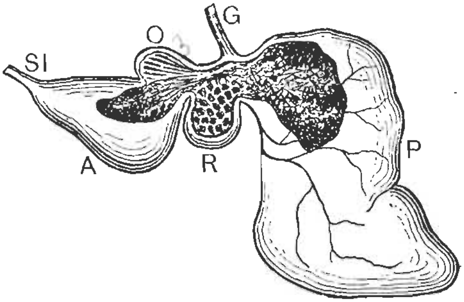


FIG. 57.—THE COW'S STOMACHS.

G. Gullet. P. Paunch or rumen.
R. Reticulum or "honeycomb." O. Omasum or manyplies.
A. Abomasum or "rennet stomach." SI. Commencement of small intestine.

really a storeroom where hastily-eaten food can be kept until the cow has an opportunity of masticating it more thoroughly.

Chewing the Cud. Everyone has seen cows ruminating or "chewing the cud." This is an important process of re-chewing, through which the food has to pass before it can be properly digested. Part of the food which has been stored in the paunch enters the second stomach or **reticulum**, a small bag with honeycomb walls. Here is it rolled into a ball. This ball of food is then drawn up through the gullet into the mouth again, and receives a thorough chewing. It

passes down the gullet a second time and is directed into the **omasum**, or third stomach, through a channel made by a fold in the lining above the second stomach.

The omasum, or third stomach, is often called the **manyplies**. The lining of its walls is thrown into a number of folds, between which the food receives a final rubbing before entering the fourth stomach.

The **abomasum**, or fourth stomach, is frequently known as "the rennet stomach," because it is from this organ in the young calf that rennet is obtained. In size it is larger than either the reticulum or the omasum, but it has only one-tenth the capacity of the paunch. It is in this fourth stomach that the true process of digestion takes place.

The stomach walls contain thousands of little glands which pour out streams of an acid liquid known as gastric juice. This juice acts rapidly upon the finely-divided food, and extracts from it much of the digestible portion. The food next passes through an opening at the other end of the abomasum into the small intestine, where digestion is practically completed. The contraction of the muscles in the walls of the intestine produces the peristaltic or worm-like motion previously referred to. This forces the food into and through the large intestine, at the end of which any undigested matter leaves the body. The digestible portion of the food, which is taken out by the juices of the stomach and intestines, is converted into a pale yellow liquid called **lymph**. Sooner or later this enters the blood-stream, by which it is carried to all parts of the body to supply energy and to build up new tissues. Some of the lymph is absorbed immediately by blood-

vessels in the intestine walls, but the greater portion is carried away through a narrow tube called the **thoracic duct**, and emptied into the blood-stream near the heart.

The Blood-supply of the Udder. The material from which milk is made is originally obtained from the food which is digested in the alimentary canal. It enters the blood-stream in the manner just described

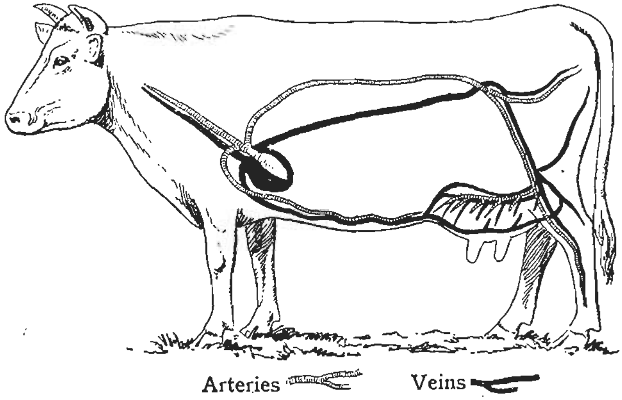


FIG. 58.—BLOOD-SUPPLY OF THE UDDER.

and is conveyed to the udder by a large blood-vessel called the **mammary artery** (*mamma* = teat).

On nearing the udder, this artery divides and subdivides into many branches which form a fine network of capillaries all through the udder. From the contents of these capillaries the milk is formed. The capillaries are then collected together into large veins, through which the blood is carried back to the heart. These veins are called **milk-veins**, although, of course, they contain blood, not milk. They can easily be felt by

passing the hand along the cow's body slightly forward of the udder.

In good dairy cows these veins are very prominent. The size of the milk-veins is an indication as to the amount of blood which is supplied to the udder, and so large veins are a good sign. If we follow the milk-veins as far forward as possible, we find that they suddenly disappear into openings in the body-wall, which can easily be felt with the finger. These openings are known as the "milk-wells" or "milk-fountains." There should be one of these milk-wells for each branch of the milk-veins. To a certain extent they regulate the capacity of the veins, and so large openings are very desirable; if too small, they will restrict the flow of blood, and consequently diminish the production of milk.

The Structure of the Udder and the Formation of Milk. The udder is a bag of tissue which hangs beneath the hind part of the cow's body. Its internal structure, as will shortly be seen, is very complex. The greater part of the substance of the udder consists of a soft, spongy, grayish-pink mass, which is made up of muscle, blood-vessels, nerves, and fat. Above each of the teats, which are generally four in number, is a **milk-reservoir**. As the name indicates, the milk-reservoirs are intended to contain the milk which is made in the other parts of the udder. Each reservoir has a capacity of about one pint. A vertical partition runs lengthwise, from back to front, through the udder, and divides it into two distinct and similar parts, each of which is called a **milk-gland**. These milk-glands have a very complex structure. Small

blood-vessels and capillaries carry blood through every part of the organ, and together with them are to be found large numbers of nerves, which regulate the flow of blood and control the formation of milk. The remaining substance of the milk-glands consists chiefly of a large number of small round bags known as **gland-lobules**.

These gland-lobules are arranged very much like grapes upon a stalk. Corresponding to the main stalk,

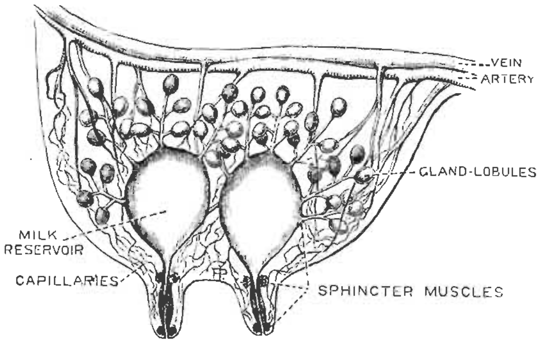
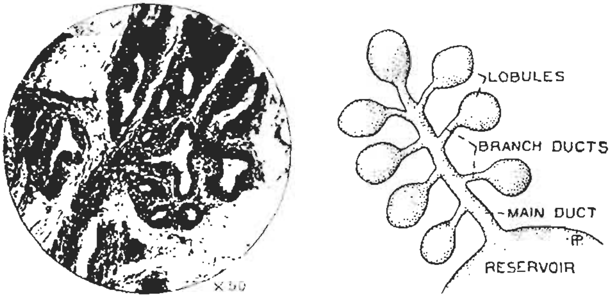


FIG. 59.—A SECTION THROUGH THE UDDER.

there is a narrow tube, known as the **milk-duct**. At intervals along this main milk-duct, smaller tubes branch out, and at the end of each of these branches we find a round gland-lobule. (Do not confuse the word " lobule " with " globule.")

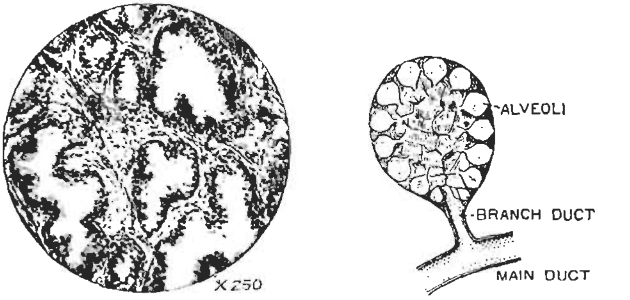
When examined under the microscope, the inside of each gland-lobule is found to be lined with a large number of small bodies called **alveoli**. They are round at one end, and taper somewhat to a neck at the other. These alveoli are very small, but they are most important, for it is in them that the milk is formed. In some

peculiar way, which is not quite understood at present, the alveoli take from the blood and lymph those substances of which milk is composed, and pass them through the neck of the lobule into the branch milk-



Section from udder of cow. A group of gland-lobules.

Fig. 60.



Alveoli. The inside of a lobule, showing alveoli.

Fig. 61.

duct. The milk enters the main duct, and then runs down into the reservoir, where it remains until the cow is milked.

From the bottom of each reservoir a tube leads down through the teat beneath, but the milk is prevented from escaping by rings of muscle around the tube.

Muscles of this type, which keep a tube closed when they are contracted, are called **sphincter muscles**. One of them is found at the top of each teat, and a more powerful one at the bottom. Other sphincter muscles, but not so well developed, are found guarding the mouths of the ducts which convey milk from the gland-lobules into the reservoir. The cow can control these muscles to a very considerable extent, and, if in a bad humour at milking time, she will cause them to contract, and so hold back the milk. If only for this reason, cows should be kindly treated; some animals are naturally difficult to milk, but many more have been made so by harsh treatment.

Milk is made during Milking. The reader may have wondered how it is that a cow can give ten quarts or more at a milking when the total capacity of the milk-reservoirs is only about two quarts. The reason for this apparent impossibility is quite simple—the greater part of the milk is made during milking. The milk waiting in the reservoirs is small in quantity and poor in quality; the largest and richest portion is manufactured during the actual process of milking.

Pressing the teats excites the network of nerves in the milk-glands, and so causes the alveoli to perform their work with greatly increased vigour; drops of rich milk trickle down the milk-ducts into the reservoirs.

Here, again, is a most important reason for treating the cow kindly, especially at milking-time. Not only can she make herself difficult to milk by contracting the sphincter muscles of the teats, but she has also a good deal of power over the formation of milk in the gland-lobules. Consequently, if put into a bad temper

by unkindness, she will retaliate by restraining the action of the milk-forming alveoli, and so cause the farmer to lose much of the most valuable part of the milk.

Any little consideration which will give the cows a feeling of greater contentment during the milking is well worth while. If possible, they should be milked in the same place, in the same order, and by the same person each day. A little clean hay to chew during milking helps to produce contentment. The milking should be done gently, but firmly and thoroughly.

Sore teats should be respected; a little vaseline rubbed on them will make milking easier and more pleasant both for cow and for milker. Milking by pulling the teats between finger and thumb is entirely wrong. The hand should be closed over the teat, beginning at the top, and pressing the teat against the ball of the thumb.

Complete "stripping" is very important. If a cow is only half milked, she will reduce her milk-yield accordingly. Thorough milking develops the udder and helps to maintain a large milk-yield.

QUESTIONS ON CHAPTER XVII.

1. Explain carefully the structure of a milk-gland.

2. What are the following: abomasum, hock-joint, thoracic duct, sphincter muscles, pelvis, tibia?

3. Describe the structure of a cow's stomachs. What is "chewing the cud"?

4. Explain how food is digested.

5. Give an account of the work of the lungs and the circulation of the blood.

6. Why should a cow be kindly treated, especially at milking time?

CHAPTER XVIII.

THE FEEDING OF DAIRY CATTLE.

The Feeding of Dairy Cattle. Owing to the great difference in fodders obtainable in different localities, this chapter cannot attempt to do more than deal with just the general scientific principles upon which all feeding should be based. The farmer must see that *the foods which are available in his own particular* district are given to his cattle in accordance with these principles.

Dairy cows require food for several purposes :

1. To build up the body.
2. To supply energy.
3. To produce heat.
4. To make milk.

First of all, the animal requires a certain amount *of food to supply the needs of the body. This is the* first use to which the animal puts its food, and only that food which is in excess of the amount required for maintaining the body is used for producing milk. Not all animals require the same amount of food ; for economical feeding, each cow should be considered separately. One animal may be overfed on a ration which would half starve another. The food which a cow receives should vary according to her yield of milk.

The Classes of Food. All foods contain more or less water, which, of course, cannot be utilized for building up the body or producing energy. It is upon the dry matter that the value of a food depends. Not all the dry matter is of value, however, for a considerable portion is not digestible. Only that portion of the dry matter which can be digested by the juices of the stomach and intestines and absorbed into the system is valuable as food.

A hundred pounds of red clover, for example, contain about 71 lb. of water and 29 lb. of solids, 18½ lb. of which are digestible. The digestible portion consists of three important classes of substances. They are known as proteids, fats, and carbohydrates; only those substances which belong to one or another of these classes are available for the nourishment of the animal.

The 18½ lb. of digestible matter in 100 lb. of red clover consist of 3 lb. of proteids, 14·8 lb. of carbohydrates, and 0·7 lb. of fat.

Proteids. Proteids are the most important of all foods, because they alone contain nitrogen, which is essential to all living things. They are used by the animal in the production of energy, the building-up and repair of the body, and the production of milk.

Proteids play a very important part in milk-formation, about one-half of them being utilized for this purpose. This nitrogenous matter, often called "protein," is the most expensive of the three classes of food substances. Leguminous crops, such as lucerne, peas, and clovers, contain a high percentage of protein.

Carbohydrates and Fats. Carbohydrates and fats are often classed together, because, although quite

different in many respects, they contain the same chemical elements, and are used by the animal for the same purposes. They contain no nitrogen, but consist of carbon, hydrogen, and oxygen.

Carbohydrates are specially plentiful in maize, oats, wheat, and grasses in general. In most cereals the carbohydrate material occurs in the form of starch granules. They are not used for the building-up and repair of the tissues, but for the production of heat to keep the animal warm, and of energy to keep up the functions of the body.

Carbohydrates also enter into the composition of milk. Lactose and the various other sugars are carbohydrates.

Besides being valuable for the production of heat and energy, fats enter into the composition of milk, and form the fatty tissue which is stored up in the body. Linseed, cottonseed-meal, and soya beans contain a high percentage of fat ; it occurs to some extent in all grains.

Fats are more concentrated than carbohydrates, and have a higher feeding value. One pound of fat is worth $2\frac{1}{4}$ pounds of carbohydrate.

A Ration. The quantity of food given to a cow each day is known as a ration. It should contain proteids, carbohydrates, and fats in sufficient quantities and in the right proportion to supply the animal's needs. The food should not be given to the animal in too concentrated a form. There should be a sufficient quantity of moisture and sufficient bulk to enable the cow to extract the various nutritious substances from the food. Rich concentrated foods, such as corn and oil-cake, will very soon make the milk-flow dry up. Green pasture is the best food for a dairy

cow; its moisture and bulkiness make it well fitted for the cow's digestion.

The Albuminoid Ratio. An average dairy cow in full milk requires a daily ration of about 2½ lb. of protein and 15 lb. of carbohydrate. The term carbohydrate is here used to include fat as well as starch and sugars, each pound of fat being regarded as equal to 2¼ lb. of carbohydrate.

It must be noted that the ratio of nitrogenous matter (protein) to carbohydrate is that of 1 to 6; this is known as the **Albuminoid Ratio**, or sometimes the Nutritive Ratio. A food which contains digestible nitrogenous and carbohydrate matter in the ratio of 1 to 6 would thus form a well-balanced ration for a dairy cow, provided that the quantity of it required to contain the 2½ lb. of protein and 15 lb. of carbohydrate were not too small or too bulky. In many cases, however, it is necessary to use several foods in order to get the correct quantities of protein and carbohydrate.

The following table gives the quantities of water, protein, carbohydrates, and fats in 100 lb. of some common fodders:

In 100 lb.	Water.	Protein.	Carbo-hydrates.	Fats.
Lucerne - -	78	3·8	12·5	0·7
Mangolds - -	90	1·1	5·4	0·1
Lucerne hay -	7	11	39	0·9
Oats (grain) - -	10·8	10	49	4
Mixed pasture	81	2·5	10·5	0·5
Red clover - -	70·5	3	14·8	0·7
Wheat bran - -	8·4	12·5	38·3	3·4

Before we can know the suitability of any particular food for dairy cattle, it is necessary to determine the albuminoid ratio of the food; this is done in the following way:

Multiply the amount of fat by 2¼, and add the result to the amount of carbohydrates present. Divide the sum by the amount of protein, and the result will be the second figure in the ratio, the protein being represented by 1. For example, let us calculate the albuminoid ratio of lucerne. Multiply the percentage of fat (0·7) by 2¼. We find that it is equal to 1·575 per cent. of carbohydrate matter. Added to this, the 12·5 per cent. of carbohydrates makes a total of 14·075. Protein is present to the extent of 3·8 per cent. Dividing this number into 14·075, we get 3·7. The albuminoid ratio of lucerne is therefore 1 : 3·7.

In order to make a perfect ratio, a quantity of some fodder which is rich in carbohydrates should be added to the lucerne. Otherwise the cow receives a large quantity of valuable nitrogenous matter which she cannot use to the best advantage owing to the lack of carbohydrates.

The following are fodders with low nutritive ratios:

Green maize - - -	(1 : 12·5)
Timothy hay - - -	(1 : 16·5)
Oat straw - - - -	(1 : 32)
Wheat straw - - -	(1 : 93)

As examples of fodders with a high ratio of protein to carbohydrate, the following may be mentioned:

Peas - - - -	(1 : 3·2)
Wheat bran - - -	(1 : 3·7)
Linseed meal - - -	(1 : 1·6)
Lucerne hay - - -	(1 : 3·8)

The desired ratio (1 : 6) is very nearly obtained by :

Red clover - - -	(1 : 5·8)
Oats - - - -	(1 : 6·2)

Fodder Crops. The particular crops which it is advisable to grow for feeding dairy cattle, depend largely upon the climate of the locality concerned.

Sometimes it is necessary to purchase concentrated foods to mix with the fodder at hand so as to make an economical ration. Such foods are linseed-meal, corn, and cottonseed-meal. They are not suitable for feeding alone, but are used to supply the food substance which is lacking in the more bulky fodder.

When maize, clover, mangolds, and good pasture can be grown, there is no need of "commercial" foods. So long as the correct albuminoid ratio can be maintained fairly closely, the milk-yield will be good. It would be slightly increased by having the exact ratio, but the farmer must always consider whether the slight increase in the milk would pay for the concentrated foods which would have to be purchased in order to obtain it.

The rule should always be to feed as closely to the correct albuminoid ratio as is profitable; a slight departure from it will reduce the milk-yield, but the saving in cost may more than compensate for this.

For summer feeding it is difficult to find a better food than good pasture, and, in many places, pasture forms the principal winter food as well. In localities where droughts occur during the summer, crops of maize, millet, or sorghum are generally sown to supplement the grass.

For winter feeding a ration of hay mixed with roots

is commonly employed. Lucerne hay and mangolds are good fodders for this purpose. For places where the crops cannot be relied upon on account of weather conditions, ensilage can be recommended as reliable fodder, with excellent milk-producing qualities.

FIG. 62.—A MAIZE PLANT AND COB.

In the following paragraphs some of the principal fodder crops are briefly described :

Maize or Indian Corn. Maize is an excellent crop to grow, both for green feeding and for making ensilage. It yields, on an average, about 30 tons of green feed to the acre, is a rapid grower, and is suitable for feeding

green to stock during a much greater period of time than most of the grain crops.

Maize is best suited for a warm climate and a fairly loose, porous soil. It is generally sown in rows about 30 inches apart, when the weather is warm enough to allow the young plants to make a good start. Maize is one of the best foods known for keeping up the milk-flow. A New Zealand Government Experimental Farm reports that during dry summer weather the milk-yield of the dairy herd fell from 3000 lb. to 2368 lb. per day. Green maize was then fed to the cows each evening; after three days, the milk-yield rose again to 2819 lb.

Millet. Like maize, millet is well suited for use as a substitute for pasture during dry weather. Millet requires a fairly heavy soil, rich in humus, and will not do well in poor, light soils. Although not equal to that of maize, its yield per acre is large if grown under favourable conditions. Unless fed when young, most varieties of millet become too tough and woody for use as green feed; they are better suited for ensilage. (Ensilage-making is explained near the end of this chapter.)

Lucerne or Alfalfa. Lucerne is a most valuable fodder crop. Like the clovers, vetches, peas, and beans, lucerne belongs to the order of plants known as *Leguminosae*. When once established, lucerne lasts for years. It is not suitable for feeding as pasture, but, when freshly cut, forms splendid fodder for milking cattle.

When young plants are about 8 inches high, they should be mown; this causes a much thicker growth.

Lucerne should be repeatedly cut and not allowed to grow very high. During the first year the yield is

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FIG. 63.—LUCERNE.

not very large, but four or five heavy cuttings may be made during each of the succeeding years. Lucerne

makes a better hay than any other crop. The soil best suited is a deep loam; but a warm, porous subsoil is even more important, because the roots descend to a great depth; for the same reason, lucerne can successfully resist periods of drought.

Grain Crops. Oats and barley are frequently used as green feed. For this purpose, they are generally sown with a leguminous crop, such as peas or vetches, which can climb up their stalks. The nitrogen which the oats take from the soil is thus replaced by the nitrogen-fixing bacteria upon the roots of the legume. These bacteria are found in small nodules upon the roots of leguminous plants; they are able to take the nitrogen gas from the air and build it up into valuable plant foods. This food is used by the plant, but a large quantity is always left in the roots to enrich the soil after the crop has been removed.

Chou Moellier. This plant is considered by many authorities to be an excellent fodder for dairy cattle. It belongs to the same family as the cabbage, which it somewhat resembles, and gives a large yield of succulent food per acre. The plants attain a height of 7 or 8 feet, and have stout stalks surrounded by large leaves. On account of its rapid growth, chou moellier forms an excellent food for spring, when the pastures are low. For this purpose it is best sown in autumn, so that it may become established and be ready to make rapid growth when the warmth of spring arrives.

At the Moumahaki Experimental Farm (N.Z.), a crop of chou moellier was sown in the autumn (end of March); by the middle of September it had yielded 20 tons to the acre. Chou moellier is hardy and easily

cultivated. When full grown it yields about 40 tons to the acre. Unless fed with proper precautions, it is liable to taint the milk.

FIG. 64.—CHOU MOELLIER.
(From *Journal of N.Z. Dept. of Agriculture.*)

Turnips. There are two main classes of turnips—the common soft turnip and the swede. Swedes can be recognized by the neck, from which their leaves are produced. Ordinary turnips have no neck, but produce the leaves directly from the crown. Hybrid varieties,

which are generally a cross between a soft turnip and a swede, are also common.

All turnip crops give the best result in a fairly cold climate. They are very useful as a winter feed. A serious objection to turnips is the fact that they give the milk an objectionable flavour. By careful feeding or by pasteurizing, however, this can be overcome.

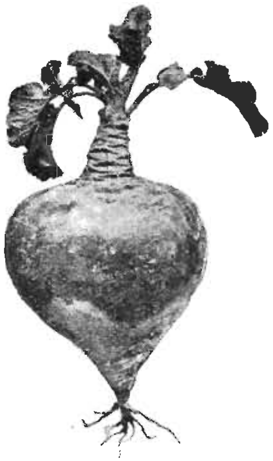

FIG. 65.—A SWEDE TURNIP.

Mangolds. Like turnips, mangolds form an excellent feed for winter and spring. Mangolds are more nutritious than turnips, and have no injurious effects upon the flavour of milk or butter. If fed as soon as they are pulled from the ground, mangolds are liable to disagree with the cows; to avoid this, they should be stored in heaps for about six weeks before use.

Mangolds give a very heavy yield per acre; on good soil 40 to 50 tons is an average crop.

Ensilage. For the purpose of milk-producing, ensilage has been proved to be much more valuable than hay. Almost any of the forage crops are suitable for making ensilage, but especially those which produce a heavy yield of succulent stems and leaves. Instead of being allowed to get thoroughly dry, as for hay-making, the crop is cut when the maximum amount of succulent fodder has been produced. It is then either

made into a stack or put into a large container known as a "silo." Everyone knows that hay, if stacked when green, would quickly become rotten and be useless for feeding to stock. This is because millions of germs attack the wet fodder and decompose it.

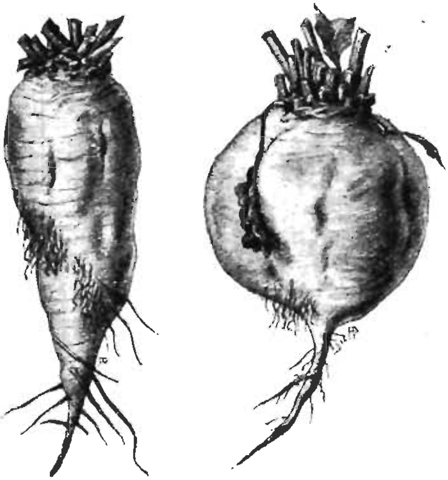

FIG. 66.—MANGOLDS. "Long" and "Globe" varieties.

In ensilage-making, the bacteria are allowed to act upon the green material to a limited extent, as this makes it better for feeding purposes (just as cheese is made more digestible by the action of bacteria during "curing"). Their action is then stopped by pressing the heap down tightly so as to exclude the air, without which the bacteria cannot carry on their work.

For making "green ensilage," bacterial activity is allowed to continue until the heat produced by the

chemical changes reaches about 130 degrees Fahr. It is then stopped by pressing the heap tightly together.

Sometimes the temperature is allowed to rise to 160 degrees; this produces brown ensilage. If the temperature rises above 160 degrees, the ensilage will be of little value.

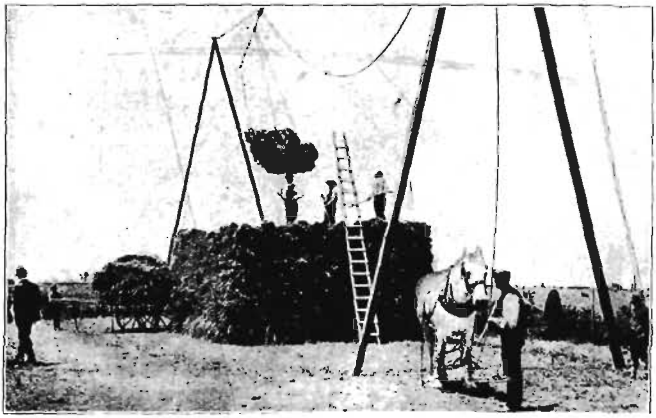

FIG. 67.—MAKING STACK ENSILAGE. (From *N.Z. Agric. Journal.*)

This process of "cooking" is very important and, so that it can be properly regulated, a galvanized iron pipe should be placed in the middle of the ensilage stack, down which a thermometer can be lowered from time to time.

Silos are constructed of concrete, sheet-iron, or wood, and are best made cylindrical in shape. Doors are provided at intervals from top to bottom, so that the ensilage can be taken out easily. On the top of the heap a platform is made and weighted down with earth or other heavy material; this compresses the

ensilage and checks any further action on the part of bacteria. If properly made, the whole of the ensilage in a silo will be excellent milk-producing fodder. The outside of stack ensilage, however, generally becomes too much decomposed to be of use. For this reason it is not considered profitable to make ensilage stacks containing less than 25 tons.

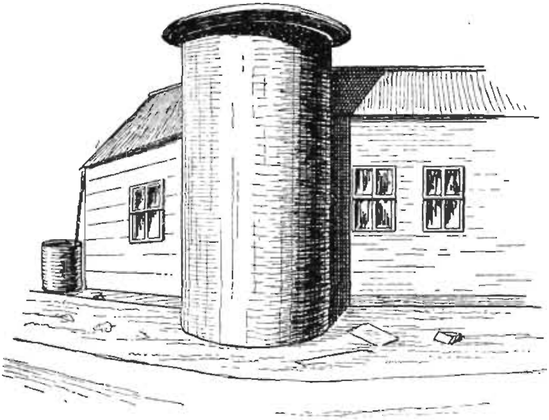

FIG. 68.—A SILO FOR ENSILAGE-MAKING.

Ensilage costs more than hay, but is a much better food for dairy cattle. It can be made in any weather, wet or dry. Any weeds which are in the crop are cut before they have time to seed, and so the ground is kept clean. Ensilage can be kept for several years, and is always a stand-by when green forage fails.

For ensilage-making, most crops should be cut during flowering. Oats, peas, clovers, lucerne, millet, sorghum, and especially maize, are all excellent crops for ensilage.

Care of the Calf. Except when bred for special purposes, the young calf is very rarely allowed to have its mother's milk in the natural way. Butter-fat is too valuable to be used as calf-food, and so the calf is given skim-milk, together with some substitute for the fat. The calf should be allowed to stay with the mother for a day at least, so that it may get the colo-

FIG. 69.—A STACK OF ENSILAGE. Eighteen months old. (From *N.Z. Agric. Journal.*)

strum milk, which acts as a tonic to its digestive system. For the first three weeks the calf should receive new milk, the quantity increasing from about 6 to 10 lb. Skim-milk is then gradually substituted for the whole milk, taking about a week to make the change. The skim-milk should be fed warm, from 90 degrees to 100 degrees Fahr. When the calf is about three weeks old, it should be given a little meal, such as crushed oats or linseed.

Linseed jelly is frequently added to the skim-milk

as a substitute for butter-fat, and calves thrive well on it. It is made by thoroughly boiling linseed in water (about one part of linseed to eight parts of water); a cupful is added to each calf's allowance of skim-milk. When calves are turned out to graze, they should be given sweet, clean pasture, and plenty of pure water.

QUESTIONS ON CHAPTER XVIII.

1. What are proteids, carbohydrates, and fats? Compare their uses as foods.

2. Explain, by means of an example, the meaning of "albuminoid ratio."

3. What is ensilage? Give a brief account of two crops suitable for ensilage making.

4. Calculate the albuminoid ratio of mangolds.

5. How should a calf be fed during the first few weeks of its life?

6. 40 lb. of red clover are mixed with 30 lb. of lucerne. Calculate the albuminoid ratio of the mixture.

7. Why is a diet of highly-concentrated foods unsuitable for dairy cattle?

CHAPTER XIX.

POINTS OF A COW.

THERE are two main ways of estimating the value of a dairy cow :

1. By her production.
2. By her shape.

The former is the more satisfactory of the two, and, in fact, is the only certain method by which the worth of a dairy cow can be ascertained.

In order to judge a cow in this way, it is necessary to take regular and careful records of her yield of milk and its fat-content. The amount of fat produced during the lactation period can then be calculated from these records. Animals yielding less than 200 lb. of fat in the year are regarded as unprofitable and should be got rid of. A yield of 300 lb. fat is very satisfactory, 350 good, and 400 very good.

When buying dairy cattle, it is important to remember that the best is generally the cheapest, and that good milking-records furnish a better indication of the value of a cow than breed, pedigree, shape, or anything else. In most cases, however, owing to the absence of such records, we are compelled to form our estimate of a cow by observing the form of her body

and comparing it with what is generally recognized as the ideal type.

The cows which are noted for their large production of milk and butter-fat have been found to possess certain well-marked common characteristics. The shape of the head, the expression of the eyes, the wedge-shaped form of the body, and, more especially, the development of the udder, are recognized as reliable indications of a cow's milking qualities.

Whether the ideal form causes a high milk-yield, or a high milk-yield tends to give the animal the ideal form, is still uncertain. Most probably, form and production mutually influence each other; form develops production, and production develops form. It is certain, however, that certain features of form are necessary for high milk-yield, and, conversely, that large yields of milk are produced by cows which possess these features. On this account, then, the shape of a cow is generally considered to indicate her value almost as accurately as the actual milking-records.

The Ideal Type. The form of a cow should be such as will tend to produce the greatest possible development of those organs which are specially concerned with the formation of milk.

There should be breadth between the hips to allow of thorough udder-development, a vigorous and capacious circulatory system to convey to the udder those materials from which milk is formed, strong jaws to masticate the food, and capacious digestive organs to digest it.

The general shape of an ideal cow is wedge-like or triangular. When viewed from the side, the body

should appear wedge-shaped, sloping down from the head to the greatest depth between the hips and bottom of the udder.

The appearance of the cow when viewed from above is also wedge-like. The greatest width should be between the hips, and the apex of the wedge at the withers.

The circumference of the body is thus greatest in the region of the hips, which is specially concerned with those organs upon which milk-production largely depends.

Her coat should be smooth and soft, and her body angular, loose-jointed, and sparely fleshed. In appearance, she should be rather thin, this being due, not to ill-health or inability to benefit by her food, but to her habit of producing milk rather than flesh. A dairy cow should be sensitive and inclined to nervousness, but not irritable or vicious.

The Head. The muzzle should be broad, and the jaw strong. The strength of the jaw can be ascertained by feeling the size of the bone and the muscles which connect it with the upper jaw. Well-developed jaw and muzzle indicate that the animal is a good feeder.

The eyes are very important; they should be large, clear, expressive, mild, and quiet. The eyes furnish a good indication of the animal's temperament.

The face should be rather long, thin, clean-cut, and free from much flesh. The forehead should be large and broad, for behind it is the brain, which is the centre of the nervous system. The ears should be of medium size, fine in texture, and contain an abundant quantity of a yellow, waxy secretion.

Forequarters. The neck should be smooth, rather slender, and sloping evenly to the shoulders. It should be free from much flesh, as this indicates a tendency to produce beef. The dewlap should be scanty. Width between the shoulders and depth of chest are desirable, as they give ample room for the heart and lungs. From this it follows that the forelegs should be wide apart, and set squarely under the animal's body. Although width between the shoulders is important, they should slope together upwards, and form sharp withers. Broad withers are looked upon as an indication of coarseness, and as inconsistent with dairy quality.

Body. Roundness of the body is very desirable, so as to give ample capacity for the internal organs. The ribs should be broad, wide apart, and bent well outwards, giving a capacious chest and barrel. A dip behind the shoulders, causing narrowness of the chest, is a serious defect. The loins also must be strong and broad ; successful calving depends largely upon the strength and breadth of this region.

The back should be straight and free from fleshiness. The vertebrae, of which the spinal column is formed, should not be too tightly fitted together ; the "chine," formed of vertical outgrowths from the vertebrae, should be sharp and easily felt.

Hindquarters. Breadth of the hindquarters is very important. The rump, the region behind the point of the hip joint, should be long and wide ; the size of the udder depends considerably upon this feature. The thighs should be thin and wide apart. Thick, bulky thighs, especially when the fleshiness is carried down

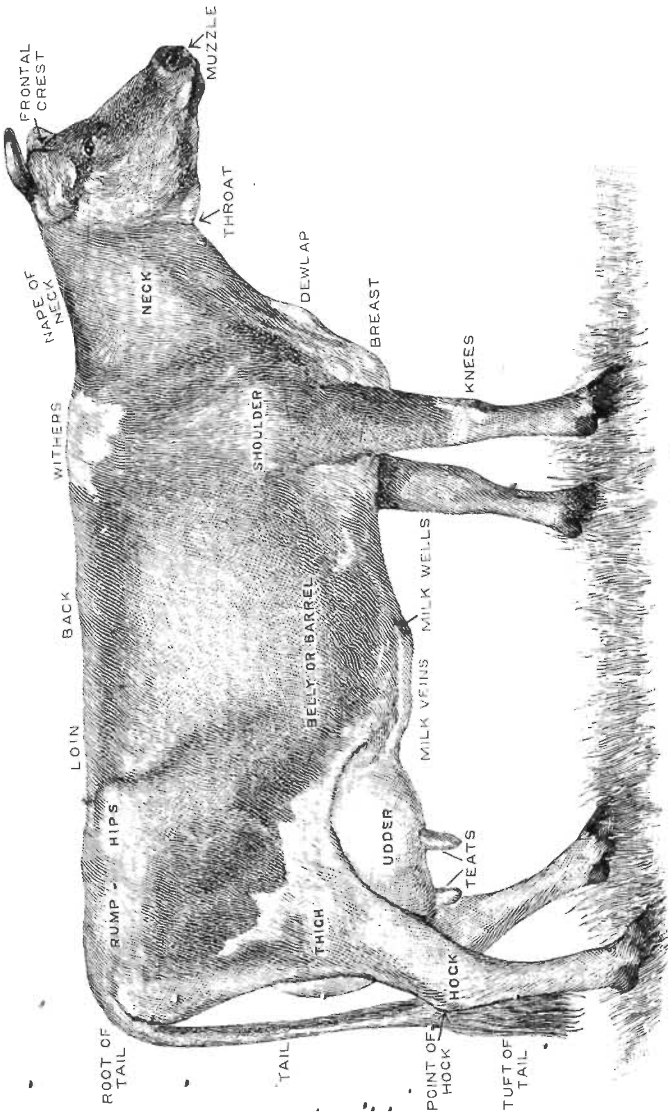

FIG. 70.—THE PARTS OF A COW.

low, occupy space which would otherwise be available for development of the udder. Though not bulky, the hind legs should be strong, upright, and set widely apart.

The Udder, etc. The development of the udder is more important than any of the points hitherto mentioned, and, in judging a dairy cow, special attention should be paid to this organ.

FIG. 71.—A PENDULOUS UDDER.
Easily soiled and injured.

The udder should be wide and long, the length being measured from its forward extremity under the body to its point of attachment behind.

Depth of udder is also very desirable, although not so important as length. A narrow, pendulous udder is objectionable because it is easily injured and dirtied. The udder should be free from excess of fat and fleshiness, or else there will not be sufficient room for the milk-forming glands. The skin of the udder should be covered with fine, silky hairs and, after milking, should hang in loose elastic folds.

The teats should be uniform in size, rather large for preference, and evenly placed, so that they can be milked without inconvenience. The escutcheon is generally looked upon as an indication of milk-

producing ability. This is an area at the back of the animal, just above the attachment of the udder. It is covered with hairs which point *upwards*, instead of downwards as in all other parts of the body. The escutcheon is thought to be nourished by the blood which flows into the udder, and so its size is taken as an indication of the volume of blood available for milk-formation. A more certain indication of this, however, is afforded by the milk-veins, which emerge from the front of the udder and then disappear into the body through a number of milk-wells. Most cows have two milk-veins, but occasionally three are found. The size and branching of these veins, and the size and number of the milk-wells, furnish a very reliable guide as to the quantity of blood which passes through the udder.

FIG. 72.—A FUNNEL-SHAPED UDDER. Small capacity.

FIG. 73.—A WELL-FORMED UDDER.

A Score Card. For guidance in judging cattle, a score card, or list of points, is very useful. A suitable

one for dairy cattle is here produced. It also shows the relative importance of the various parts of the animal.

A SCORE CARD FOR DAIRY CATTLE.

	Possible Points.
A. **General appearance** : 15 per cent.	
Disposition : gentle, sensitive, quiet, active, vigorous - - - - -	5
Quality : free from coarseness, hair soft and fine, skin soft and pliable - - -	5
Form : wedge-shaped, capacious body -	5
B. **Head** : 7 per cent.	
Muzzle : broad and clearly defined - -	1
Jaw : strong and firm - - - -	1
Forehead : broad - - - - -	1
Eyes : large, clear, placid - - - -	2
Ears : medium size, abundant oily secretion, fine texture - - - - -	2
C. **Forequarters** : 11 per cent.	
Neck : long, smooth, flesh scanty - -	3
Withers : narrow and sharp - - -	2
Shoulders : wide apart, sloping - - -	3
Fore Legs : well apart, straight, well under body - - - - - - -	3
D. **Body** : 24 per cent.	
Chest : deep and full - - - -	6
Ribs : long, broad, bent well out, capacious barrel - - - - - - -	12
Back : sharp, straight, vertebrae open -	4
Loin : broad and strong - - - -	2
E. **Hindquarters** : 12 per cent.	
Hips : prominent, wide apart - - -	2
Rump : long and wide - - - -	3
Thighs and Legs : not fleshy, wide apart -	4
Tail : long, tapering, fine - - - -	1
Escutcheon : wide, extending far upwards -	2

F. **Udder, etc.** : 32 per cent.	Possible Points.
Udder : long, high behind, well-formed, wide, deep, quarters even, not fleshy, fine elastic skin - - - - - -	20
Teats : fairly large, uniform, wide apart -	5
Milk-veins : large, tortuous, branched -	4
Milk-wells : large, numerous - - -	2
TOTAL - - -	100

QUESTIONS ON CHAPTER XIX.

1. What is the ideal shape for a dairy cow ?

2. Describe a perfectly-formed udder.

3. Explain how the character of the head indicates the milking qualities of a cow.

4. How should a cow's hind leg be shaped ?

5. Why are width between hips and a large girth behind the shoulders desirable ?

CHAPTER XX.

DAIRY CATTLE.

Beef Cattle. There are two main types of cattle, namely, Beef Cattle and Dairy Cattle. The former class includes those breeds of sturdy, square-built animals such as the Herefords, whose energies seem to be directed more to the building-up of their bodies than to the production of milk. They are not suitable for dairying purposes, and are bred for the butcher.

Dairy Cattle. Ayrshire and Holstein cattle, on the other hand, are essentially dairy breeds. Beef cattle are heavy and square-built. As a rule the dairy cow is wedge-shaped, tapering from a lightly-built head and forequarters to breadth between the hips and a large, low-hanging udder. The thing desired of a dairy cow is not beef, but milk. The size of the animal does not matter much ; a Holstein cow has almost twice the weight of a Jersey, but both are excellent milk-producers.

Dual-Purpose Cattle. We frequently hear of "Dual-Purpose Cattle." This term is applied to those breeds which are well suited both for milking and for killing. The cows with highly-developed milking qualities are not beef-producers, and when their milking

days are over, they are practically valueless. Consequently, many attempts have been made, by means

HEREFORD.

JERSEY.

FIG. 74.—BEEF AND DAIRY TYPES.

of careful breeding, to develop cattle which can profitably be milked for some years, and then easily fattened for the butchers. As would naturally be expected, dual-purpose cattle are something between

beef cattle and dairy cattle in appearance. They are not so heavily built as the Herefords, but carry more flesh than the Jerseys. They have fairly large hindquarters, but are much more squarely built than the wedge-shaped dairy animal. Shorthorn, Red-Polled, and Devon are the best known breeds of dual-purpose cattle. The Shorthorn and the Devon are bred in two distinct strains, one being better suited for beef-production and the other for dairying purposes. The result of much experience, however, seems to be that dual-purpose cattle are not the most economical in the long run. Their value as beef when dead does not compensate for a low milk-yield during many years, and it has been found impossible to combine in the same animal the beef-forming qualities of a Hereford with the high milk-yield of a Holstein. Most authorities are now agreed that, if dairying is the object, it is best to keep to a purely dairying breed.

The Best Breed. There are many breeds of cattle. Which is the best breed? We have already seen that, if dairying is the object, then one of the dairy breeds should be chosen, but the question as to which breed is best cannot be settled in a book. Everything depends upon local conditions--climate, pasture, the nature and extent of the farm. The various breeds of dairy cattle have been brought from different parts of the world, and so they have different characteristics. Coming from the warm atmosphere and rich pastures of the Channel Islands, the Jersey is not suited to a severe climate, rough country, or coarse fodder.

The Ayrshire, on the other hand, has been developed among the hills of Scotland, and so is a hardy animal

which can give good results under very trying conditions. The question as to what is the best breed also depends upon the purpose for which the milk is required—market, butter, or cheese.

Milk which is sold for human consumption is required by law to contain a certain percentage of butter-fat, generally about 3 per cent. It is obvious then that, if milk is intended for market, cows which give a small quantity of very rich milk will not be so profitable as heavy milkers like the Holsteins, which yield a large quantity of milk containing generally about 3·5 per cent. of fat. On the other hand, when milk is to be sent to the butter-factory, a large quantity of fat and not bulk of milk is desired; for this purpose the Jerseys cannot be beaten, although it must be remembered that animals of other breeds may compensate for a lower percentage of fat by a larger yield of milk.

Let us next consider the leading characteristics of the principal breeds of dairy cattle.

Breeds of Dairy Cattle. 1. **Jersey**. The Channel Islands, off the coast of France, are the home of several splendid breeds of dairy cattle. Two of these breeds, the Jersey and the Guernsey, are to be found in dairy herds in all parts of the world, where they are greatly prized for the richness of their milk. The Jersey, which comes from the island of that name, is a small animal, generally fawn-coloured. She has a very gentle disposition and responds well to kind treatment. On account of her small size (the average weight is about 800 lb.) the Jersey is very economical; she is a small eater and, provided that the pasture is good,

can be kept on a very small area. The Jersey is an ideal cow for butter-making. She gives rich, yellow milk which contains, on the average, about 5 per cent. of fat. The fat-globules are large, and so the milk creams readily. As already stated, the Jersey will not do well under hard conditions or unkind usage. If the climate is severe, the food coarse and inferior,

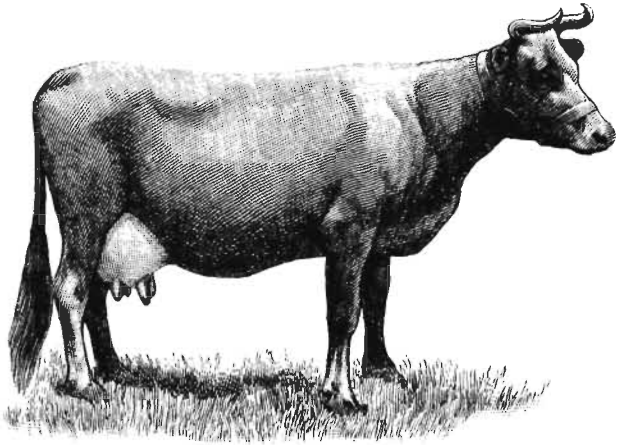

FIG. 75.—A JERSEY COW. (From *N.Z. Agric. Dept. Journal.*)

or the country rough, some other breed should be chosen. The conditions under which the breed has been developed are a warm, sunny climate, rich pasturage, and gentle treatment; only under these conditions can Jerseys give good results.

2. **Guernsey.** Guernsey cattle are very similar to the Jerseys, but are slightly larger and more vigorous. They are not so gentle or so delicate as the Jerseys, and are darker in colour. Guernseys are excellent

cows for butter-making, as the milk contains a high percentage of fat in the form of large globules.

The butter which is made from Guernsey milk is noted for its extreme yellowness; it is more highly coloured than that of any other breed.

3. **Holstein-Friesian.** This breed of dairy cattle, commonly known as the Holstein, possesses charac-

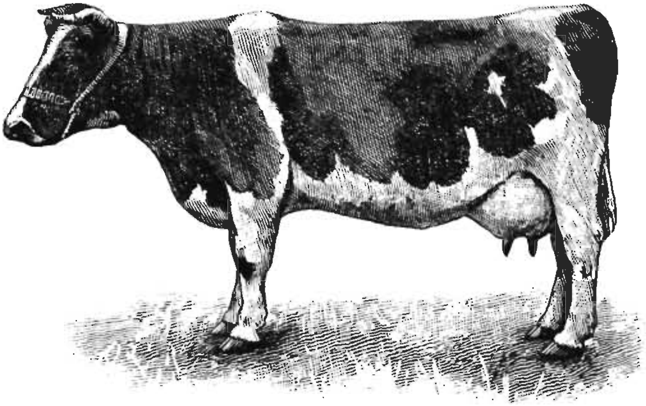

Fig. 76.—A Holstein Cow.

teristics which are very different from those of the Channel Islands breeds.

As the name implies, the original home of the breed is in the district of Holstein (north-west of Germany) and Friesland (north of Holland). The cows are unsurpassed as milk-producers, although they have been bred for many generations with a view to the "dual purpose." Holsteins are much hardier than either Jerseys or Guernseys, and can stand a considerable amount of cold. They are large animals, the largest of the dairy cattle, and are coloured black and

white in well-defined patches. The amount of each colour varies greatly, and we frequently find Holsteins which are almost pure white or pure black.

A fully-grown cow weighs from 1200 to 1400 lb., and yields a large quantity of milk containing about 3·5 per cent. of fat. The fat-globules are small, uniform in size, and pale in colour. Owing to their smallness, the milk does not cream readily by the gravity methods. On account of her large milk-yield, the Holstein is well called the "milkman's cow." Holsteins require abundance of food and plenty of room. Broad, grassy flats form an ideal pasturage for cows of this breed. On rough land, where food is scanty, they give poor results. Although the percentage of fat in Holstein milk is comparatively low, the milk-yield is so heavy that the actual amount of fat given compares very favourably with the yield of other breeds. And so the popularity of the Holsteins is steadily increasing.

4. **Ayrshire**. For rough country, scanty pasture, and a harsh climate, there is no better breed of dairy cattle than the Ayrshire. Originally from the county of Ayrshire, in the south-west of Scotland, the breed has spread over the greater part of the country, where rough pasturage and severe climate have caused it to develop into one of the sturdiest races of dairy cattle in the world.

The Ayrshires are of medium size (a full-grown cow weighs about 1000 lb.), and possess the wedge shape which is typical of dairy cows. They are usually red and white or brown and white in colour. The greater part of the animal is white, and the colour occurs in well-marked patches of various shapes and sizes.

Ayrshire cows give a good milk-yield, even from poor pasture. The milk is especially suitable for cheese-making. It is rich in casein, and the fat-globules (generally about 3·8 per cent.) are small. On this account they do not rise to the top too quickly, but

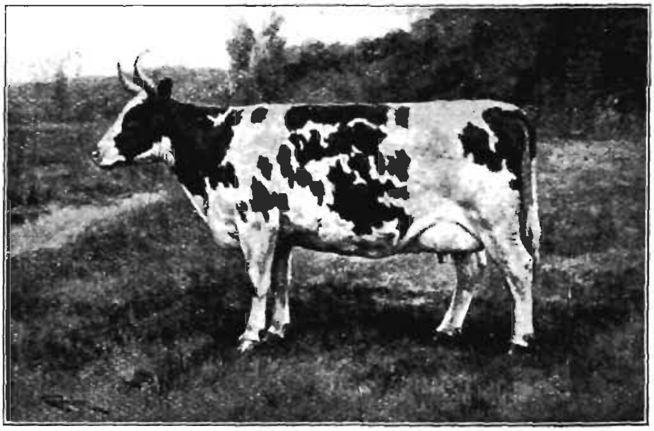

FIG. 77.—AN AYRSHIRE COW.

remain evenly distributed through the curd when it forms.

The Ayrshire thrives well in almost any climate, and after years of profitable milk-producing, she can generally be fattened sufficiently for killing.

5. **The Shorthorn.** The Shorthorn is an English breed which has been bred very largely for beef. In general, the characteristics of the Shorthorns entitle them to be classed as beef cattle, but many good dairy cows are found among them, and from such animals special strains of milking Shorthorns have been bred. The milking strain makes a good dairying breed. They

are above the average in size and weight, possess hardy constitutions, and can always be profitably turned into beef. The Shorthorn is the best known of the "dual purpose" breeds. The cows give a fair yield of milk, which contains about 4 per cent. of fat in the form of medium-sized globules. The cream separates readily by gravity methods.

The Shorthorns are rough, angular, and solid in appearance. Their colour varies considerably; it may be red, white, or roan. Generally these colours are combined.

Most of the common cross-bred dairy cows contain a large proportion of Shorthorn blood.

6. **Dutch Belted.** Animals of this breed can easily be recognized by their remarkable appearance. They are pure black in colour except for a broad white band which stretches completely round the body. The breed was developed in Holland over two hundred years ago, and the fact that the peculiar contrast of colour still keeps true is a proof that the old Dutch cattle-breeders possessed remarkable skill. In Holland this breed is called "Lakenfeld," but its name throughout English-speaking countries is "Dutch Belted."

The breed is not numerous, but the animals are satisfactory milk-producers. They yield an average quantity of fairly rich milk, and are also good beef-producers. They are solidly built, of medium size, docile, hardy, and vigorous.

Numbers of Dutch Belted cattle have been imported into England and America, but they are comparatively few, and so far the breed is not very widely known. They do not possess remarkable milking or butter-

producing qualities, and the chief point in their favour seems to be that they are steady, reliable animals, which can be trusted to give a fair margin of profit.

7. **Kerry Cattle.** This is a breed of very small cattle which comes from the south-west of Ireland. In some cases a full-grown cow does not weigh more than 500 lb. Kerry cattle are black in colour, grace-

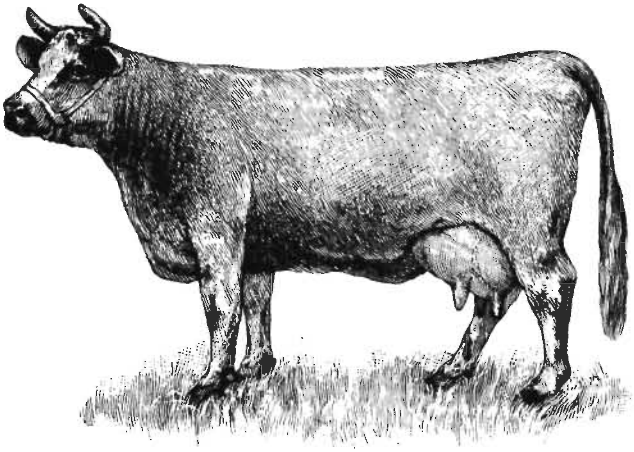

FIG. 78.—A SHORTHORN COW.

fully built, and very active. Like the Ayrshires, they are noted for their hardy constitutions, which enable them to exist on rough and scanty pasture, and at the same time to give excellent yields of milk.

8. **Brown Swiss.** This is the most prominent breed of cattle known throughout Europe. So far, it is not very numerous in other parts of the world, but seems to be steadily increasing. Brown Swiss cattle are of medium build, and vary in colour from dark brown to

a very light chestnut shade. They are splendid hill-climbers and are well suited for rough country. They are strongly and compactly built, have stout legs, and are very hardy. The milk-yield is well up to the average, and generally contains about 3·8 per cent. of butter-fat.

Brown Swiss may be included among the "dual-purpose" cattle, as they have always plenty of flesh, and can be fattened very easily when not in milk.

9. **Red Poll.** The Red Polls are a race of cattle which has been highly prized in England for many years for its excellent milking qualities. The origin of the breed is a matter of doubt. The most probable theory is that the original ancestors of the breed existed in England from the earliest times, but the Red Polls, as we know them now, are a cross between this ancient English breed and the Galloway Polls, which were introduced into England in large numbers during the eighteenth century. However that may be, the Red Polls are undoubtedly a British breed. They form one of the "dual-purpose" breeds, as they are good beef-producers; many individual cows, however, are distinctly of the dairying type.

The percentage of butter-fat is generally about 4 per cent. The Red Polls are deep red in colour, sometimes having a little white at the end of the tail. They are strong, firmly built, of medium size, and can be relied upon to give satisfactory results under ordinary farm conditions.

QUESTIONS ON CHAPTER XX.

1. What are the leading characteristics of Ayrshire cattle ?

2. Discuss the advantages and the disadvantages of "dual purpose" cattle.

3. Contrast Jersey cattle with Holsteins.

4. What breeds are noted for (*a*) large milk-yield, (*b*) richness of milk, (*c*) hardy constitution ?

5. Contrast the ideal type of a dairy cow with that of an animal bred for beef.

CHAPTER XXI.

SOME DISEASES AFFECTING DAIRY CATTLE.

Contagious Mammitis. Contagious mammitis is a disease of considerable importance to the dairy industry. Like other contagious diseases, it is due to the action of bacteria. The bacteria which cause contagious mammitis attack the delicate membranous lining of the milk-ducts in the cow's udder, and have a very serious effect upon the production of milk. These germs belong to the class of minute circular organisms known as *streptococci*. They occur in chains of from four to ten, and resemble in appearance the microbes which cause abscesses in human beings.

Mammitis germs are capable of rapid multiplication, but the cow is able to check their growth very considerably, and, unless they are present in large numbers, to destroy them altogether.

The blood of all animals, including man, contains small white bodies of indefinite shape, known as "white corpuscles" or "leucocytes." In the blood of healthy animals they are plentiful, but not so many are found in the blood of animals which are diseased or in bad health. When one understands the function of leucocytes, it is easy to see the reason for this

difference. Their work is to act as soldiers in the blood. When any undesirable germ enters the blood, it is immediately attacked by one of these soldiers. The leucocyte gradually closes round the intruder, and, if strong enough, destroys it.

Sometimes, however, the germ proves to be the stronger of the two. It destroys the leucocyte and at the same time produces more germs by a process of division. Each one of these new germs joins in the fight against the leucocytes. If the animal is healthy, the leucocytes are plentiful and vigorous, and they will probably soon destroy all the invading germs. If not, the germs destroy the leucocytes, multiplying and gaining strength with each successive victory, until finally they completely capture the body of the unfortunate animal, and so cause its death. When the mammitis germs attack the membranous lining of the milk-ducts, large numbers of leucocytes hasten to the spot and endeavour to destroy them. But, as a rule, the leucocytes are powerless; they are massacred in thousands, and their dead bodies form cells of yellow pus or "matter." The "matter" which comes from unhealthy wounds and abscesses consists chiefly of dead leucocytes, which have fallen victims to the disease germs.

The presence of large numbers of pus cells in milk is one of the surest indications of mammitis. The milk becomes viscous and yellowish; in acute forms of the disease it assumes a dirty brownish colour, becomes quite thick, and, if allowed to stand for a time, a large part of it settles in the form of a thick mass. When examined under a microscope, this mass

is seen to consist of dead leucocytes or pus cells, and chains of streptococci.

During the progress of the disease the lining of the teat frequently hardens and causes swelling; the milk-duct may become blocked by small nodules about the size of a pea, which form on its sides. There is a

FIG. 79.—CONTAGIOUS MAMMITIS GERMS.
Pus cells and chains of streptococci in milk from a diseased udder.
(From *N.Z. Dairy Bulletin*, No. 13).

serious decrease in the yield of milk, and in some cases the affected quarter of the udder may be rendered quite useless. Up to the present no really satisfactory cure for contagious mammitis has been discovered; the best method of getting rid of the disease is to prevent it from spreading.

In districts where the disease occurs, newly-purchased cows should not be allowed to mix with the herd until

they have been proved free from infection. If a cow is found to be suffering from mammitis, every precaution must be taken to prevent it from spreading to the other members of the herd. She should be isolated, if possible, and must on no account be milked with the milking-machine.

The best way is to milk her into a special bucket, boil the milk immediately, and give it to the pigs. The milker's hands should be thoroughly washed in hot water containing soap and disinfectant before he touches other cows. If these simple precautions are neglected, the whole herd may contract the disease. The effect of mammitis is usually confined to the organs of milk-production, but in serious cases the result may be fatal. If the disease is detected early enough, repeated injections of warm boracic acid solution into the udder will frequently cure it. But this treatment is not effective except in the very early stages, because the germs penetrate into the tiny branches of the milk-ducts, where they cannot be reached by the injection. Moreover, a disinfectant of sufficient strength to destroy the germs is almost certain to injure the inside lining of the udder and probably do more harm than good. For the average farmer, however, it is best not to attempt to cure a cow suffering from mammitis. The best plan is to dry her off, let her fatten for killing, and meanwhile take every possible precaution to prevent the other members of the herd from contracting the disease.

Tuberculosis. Tuberculosis is a disease which occurs in animals and in human beings in all parts of the world. It attacks all parts of the body, especially the

lymphatic glands. Tuberculosis is known by various names. "Consumption" and "phthisis" are terms used to denote tuberculosis of the lungs in man. "Lupus" is tuberculosis of the skin. "Grapes" and "pearl disease" are names sometimes applied to certain forms of the disease in cattle.

Tuberculosis is caused by rod-shaped bacteria known as *tubercle bacilli*. When dry, these bacteria float about in the air as dust, and so are frequently breathed into the lungs. The organs most liable to be attacked are the lymphatic glands. These are soft, oval structures occurring in various parts of the body, such as the throat, intestines, and lungs. In these glands the tubercle bacilli are attacked by leucocytes. If the latter are defeated, their dead bodies form pus cells which block the gland, causing it to swell and become a mass of diseased tissue. The bacteria are carried on in the lymph and blood to various parts of the body, where they attack similar glands and other organs as well. As a rule, the effect of tuberculosis is to cause a swelling of the diseased organ. Round lumps, called tubercles, are formed, and increase in size as the disease advances. The tubercles contain large numbers of bacilli; the larger tubercles are frequently filled with yellow pus. In cattle the parts most frequently affected are:

1. The lymphatic glands at the base of the skull, on either side of wind-pipe and gullet.
2. The lymphatic glands on the wind-pipe between the lungs.
3. The lymphatic glands of the intestines.
4. The lungs.
5. The liver.
6. The spleen.
7. The udder.

Tuberculosis of the Udder. Tuberculosis of the udder is comparatively rare, occurring in about 2 per cent. of the total number of cases. It is very important, however, as it is certain to cause contamination of the milk, and will probably lead to the contraction of the disease by the human consumer.

The healthy udder is soft and elastic throughout; a tuberculous udder contains hard tubercles which can frequently be felt on the surface. The disease is usually confined to one quarter of the udder, which becomes enlarged and hard in the more advanced stages. The milk is usually quite normal in appearance, but may become very watery in severe cases.

General Symptoms. The symptoms vary according to the organs attacked. Sometimes, as in the case of a tuberculous udder, the tubercles can be felt as hard swellings. In most cases, however, the appearance of the animal shows no symptom of tuberculosis until the disease is well advanced, although the animal may be infecting the whole herd. As the disease advances, the animal becomes hide-bound, weak, emaciated, and finally dies. The only certain method of detecting tuberculosis in the early stages is to employ the "tuberculin test"; this very rarely fails.

The Tuberculin Test. If a small quantity of tuberculin is injected beneath the skin of an infected animal, the animal's temperature will be raised several degrees. The temperature of a healthy animal remains unaltered.

Tuberculin is a brown, syrupy liquid, made by growing tubercle bacilli in beef broth and glycerin. When the bacilli have thoroughly developed, the mass

of broth and bacilli is kept at boiling-point for five or six hours ; this destroys all germs. Their dead bodies are removed by filtration, and carbolic acid is added to prevent subsequent contamination. In this way, tuberculin is made perfectly sterile ; it cannot possibly contain any living tubercle bacilli. Before applying the test, the normal temperature of the animal is ascertained ; in the case of a cow, it is generally between 101 and 102 degrees Fahr. A certain quantity of tuberculin, usually about 2 c.c., is then injected under the animal's skin by means of a hypodermic syringe. This is generally done at the shoulder. Before the injection is made, the syringe should be sterilized in carbolic acid solution to prevent inoculation of the wound by harmful bacteria. If the animal is tuberculous, the temperature should commence to rise about ten hours after the injection. The general rule is to take the first temperature at the eighth hour after the injection, and then at intervals of two hours until the eighteenth hour at least. The temperature of a tuberculous animal usually rises 4 or 5 degrees above the normal and falls again after eight or nine hours. When the increase in temperature is about 2 degrees, the reaction is considered doubtful, and the animal is tested again at a later date.

The tuberculin test does not injure the cow whether she be healthy or tuberculous, nor does it affect the progress of the disease when it has been contracted.

Control of Tuberculosis. 1. In many countries all imported cattle are tested with tuberculin. Those which show signs of tuberculosis are refused admission to the country.

2. Except in very rare cases, tuberculosis is not inherited, but the calf can soon contract it from a tuberculous mother. Young calves should not be allowed to suck tuberculous cows.

3. All skim-milk and whey should be pasteurized at dairy factories before being returned to the farm for feeding purposes. This prevents young stock from becoming affected. In Denmark, where compulsory pasteurization has been in force for years, tuberculosis has almost disappeared.

4. Since one tuberculous animal may cause the whole herd to become affected with the disease, any cows which react to the tuberculin test should be fattened for the butcher, or at least be isolated from the other members of the herd. By occasional herd-testing with tuberculin, this dreaded disease could be detected and kept in check.

Milk Fever or Parturient Apoplexy. This is a serious disease which frequently inflicts severe losses upon the dairy farmer. It occurs in cows shortly after calving, and may cause death in a few hours. The disease is rarely noticed before the birth of the calf, but it may occur at any subsequent calving.

Milk fever most frequently affects deep-milking cows in good condition, and so the farmer's best cows are most liable to be attacked.

Symptoms. Milk fever is a form of paralysis. The first symptoms are listlessness, disinclination to take food, shivering, and a more or less complete cessation of the milk-flow. The animal loses the power of walking or standing steady, and finally falls to the ground. In some cases, she lies in a state of stupor

and persistently turns her head to one side. In other cases, the patient shows restlessness, dashing her head from side to side, and making frantic but futile efforts to rise. In all cases there is paralysis, or loss of control over the body. As the attack grows worse the state of stupor becomes more complete, the eyes become glazed and expressionless, the breathing grows noisy and difficult, and unless proper treatment is applied, death soon follows.

Treatment. As a preventive measure, a drench may be given to those cows which seem likely to be attacked, but little good can be done by the use of medicines after the fever has commenced. So long as the animal is standing, liquids may be given without much difficulty or danger. After she has fallen, however, and has lost the power of swallowing, medicines are apt to enter the wind-pipe and so cause death by suffocation. As a general rule, the use of medicines has now been abandoned in favour of a more effective and less difficult method of treatment. This consists of injecting air into the udder. Although the actual cause of milk fever is not yet known exactly, it is certain that the udder is connected with the cause to a very considerable degree, and the best results have been obtained by treating that organ. The method of treatment is quite simple, and, provided that proper care is taken, can be carried out by any ordinary person.

Special air-syringes, fitted with an air-filter and a long nozzle, are generally used, but they are not absolutely necessary. Before the treatment is commenced, the udder should be milked dry, and then washed in warm water to which a little carbolic acid

has been added. After being thoroughly sterilized in boiling water, the nozzle of the syringe is then inserted into the duct of the teat, and pushed up to the top. As much air as possible should then be pumped into the udder by squeezing the bulb of the syringe in the usual way. Each quarter of the udder should be treated in turn, and when this is completed, the whole udder should be gently massaged in order to work the

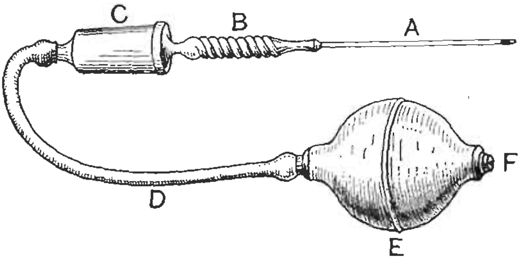

Fig. 80.—Syringe for injecting Air into a Cow's Udder.

A. Nozzle. B. Handle. C. Air-filter.
D. Rubber tubing. E. Rubber bulb. F. Valve.

air into all parts of the organ. It is extremely important that only clean air should be pumped into the udder; dust and germs would do considerable harm to the delicate linings of the milk-ducts.

The syringe should be fitted with an air-filter of disinfected cotton-wool, especially when it is to be used inside a shed or barn. If applied in the early stages of the attack, with proper sanitary precautions, this method of treatment will generally result in a complete cure.

QUESTIONS ON CHAPTER XXI.

1. (*a*) What are the symptoms of milk fever? (*b*) How would you treat a case of milk fever?

2. In cases of contagious mammitis, large quantities of pus are formed. Explain this.

3. Say what you know about the tuberculin test.

4. What are the symptoms of contagious mammitis?

5. What measures can be taken to prevent the spread of tuberculosis in dairy cattle?

CHAPTER XXII.

DAIRY ARITHMETIC.

Some Important Facts.

1 gallon = 4 quarts = 8 pints.

1 lb. butter-fat should make $1\frac{1}{6}$ lb. butter.

1 gallon of average milk makes 1 lb. of cheese.

A quart of milk weighs 2·58 lb.

A gallon of milk weighs 10·32 lb. (10 lb. 5 oz.).

(For ordinary practical calculations, the weight of a gallon of milk is reckoned as 10 lb.)

100 lb. of average milk yield about 10 lb. of thick cream and 90 lb. of skim-milk.

A gallon of water weighs 10 lb.

A. The Composition of Dairy Products.

EXAMPLE (*a*). What weight of fat will be yielded by 560 lb. of milk testing 3·8 per cent.?

In 100 lb. milk there are 3·8 lb. fat.

" 1 " " $\frac{3 \cdot 8}{100}$ "

" 560 " " $\frac{3 \cdot 8}{100} \times 560$

$= \underline{21 \cdot 28 \text{ lb. fat.}}$

EXAMPLE (*b*). What weight of whey, containing 5·2 per cent. of lactose, is required to yield 20 lb. of lactose?

5·2 lb. lactose are yielded by 100 lb. whey.

1 " " " $\frac{100}{5 \cdot 2}$ "

20 " " " $\frac{100}{5 \cdot 2} \times 20$

$= 384 \cdot 6$ lb. whey.

Exercise A.

(1) How much fat is contained in 165 lb. of milk testing 3·8 per cent. fat?

(2) Find how many pounds of fat are in 85 lb. of buttermilk, testing 0·12 per cent. fat.

(3) Each day a certain cow gives 40 lb. of milk, testing 4·5 per cent. fat. How many pounds of fat will she give in a week?

(4) What weight of cream, testing 40 per cent. fat, will yield 32 lb. of fat?

(5) What weight of proteids is there in 100 gallons of milk? (casein 2·5 per cent., albumen 0·7 per cent.).

(6) If butter contains 14 per cent. of water, what is the weight of solid matter in 3 cwt. of butter?

(7) How many cows, each giving an average daily yield of 35 lb. of milk (4 per cent. fat) are needed to yield 28 lb. of fat per day?

B. Calculating Losses.

EXAMPLE. If the skim-milk from a separator contains 0·15 per cent. of fat, how much worth of fat (at 11 pence per lb.) would be lost in separating 800 gallons of milk?

800 gallons milk weigh 8256 lb.

This should yield about 7430 lb. of skim-milk.

$$\text{Weight of fat in skim-milk} = \frac{0{\cdot}15}{100} \text{ of } 7430 \text{ lb.} = 11{\cdot}145 \text{ lb.}$$

$$\text{Value of fat at } 11 \text{ pence per lb.} = 11 \times 11{\cdot}145 = \underline{10\text{s. } 2\tfrac{1}{2}\text{d.}}$$

Exercise B.

(1) What value of fat, at a shilling per lb., would be lost from 1000 ~~gallon~~s of milk by a separator which leaves 0·2 per cent. of fat in the skim-milk ?

(2) On account of turning the handle too slowly, the percentage of fat in the skim-milk is increased by 0·05 per cent. What would be the value of the fat (at a shilling per lb.) so lost in 15,500 lb. of skim-milk ?

(3) From 200 lb. of milk testing 5 per cent. fat, a farmer gets 30 lb. of cream testing 33 per cent. How many pounds of fat are lost in skimming ?

(4) Supposing 0·015 per cent. fat in milk to be lost during skimming, calculate how many pounds of fat would be lost from 5000 lb. of milk testing 4 per cent. fat ?

(5) How many pounds of 40 per cent. cream could be obtained from 4600 lb. of milk testing 4·5 per cent. fat, supposing 0·01 per cent. fat to be lost in skimming ?

C. Computing Overrun.

EXAMPLE (*a*). Supposing the overrun to be 15 per cent., how many pounds of butter can be made from 200 lb. of 40 per cent. cream ?

$$\text{Weight of fat in cream} = \frac{40}{100} \times 200 = 80 \text{ lb.}$$

$$\text{Since } 1 \text{ lb. of fat makes } 1\tfrac{15}{100} \text{ lb. of butter,}$$

$$\text{weight of butter} = 1\tfrac{15}{100} \times 80 = \underline{92 \text{ lb.}}$$

EXAMPLE (*b*). From 1000 lb. of cream testing 35 per cent. fat, 400 lb. of butter are made. Calculate the percentage of overrun.

$$\text{Weight of fat} = \frac{35}{100} \text{ of } 1000 = 350.$$

$$\textit{Weight of overrun} = 400 - 350 = 50.$$

$$\text{Percentage of overrun} = \frac{50}{350} \times \frac{100}{1} = \underline{14{\cdot}28 \text{ per cent.}}$$

Exercise C.

(1) From 1000 lb. of cream testing 35 per cent. fat a butter-maker produces 420 lb. of butter. Calculate the percentage of overrun.

(2) Supposing the overrun to be 16 per cent., how many pounds of butter can be made from 800 lb. of cream testing 40 per cent. fat ?

(3) If butter is worth 1s. 2d. per lb., calculate the value of the overrun in the last question.

(4) A farmer has ten cows, from each of which 250 lb. of fat are obtained yearly. If the average overrun is 12 per cent., calculate the weight of a year's overrun from the herd's yield.

(5) By more careful management the farmer mentioned in the last question increases his overrun to 15 per cent. Supposing butter to be worth 1s. 1d. per lb., find how much greater his receipts are per year.

D. Creamery Dividends.

Some creameries are owned by private individuals, or by companies, and others are co-operative ; that is, they are owned by the suppliers themselves. There are several systems of conducting co-operative dairy

factories. In some cases the total monthly expenses are deducted from the receipts, and the balance is divided by the number of pounds of fat delivered by the patrons; the quotient is the amount paid per pound for the fat supplied during the month.

Another method is to pay a fair price per pound for the fat, and then, generally yearly or half-yearly, to divide the profits amongst the various shareholders proportionally to the amount of money which each has invested in the creamery. Each day, when milk arrives at the creamery, it is weighed and a small sample is taken. The samples of each patron's milk are put together in a bottle with preservative; the percentage of fat in the mixture is determined by the Babcock test, generally twice a month, but sometimes more frequently. From the weight of milk and the percentage of fat, the weight of fat can easily be calculated, and the patrons are paid accordingly.

EXAMPLE. The following table shows the weight of milk, the fat-tests, and the weight of fat supplied by each of five patrons. The amount of money due is reckoned on the assumption that a shilling per pound is being paid for the butter-fat.

Patron No.	Pounds Milk.	Fat Test.	Pounds Fat.	Amount Due.
1	940	4·2	39·42	£1 19 6
2	3500	5·0	175·00	8 15 0
3	775	3·9	30·22	1 10 2½
4	600	4·6	27·60	1 7 7
5	1400	4·5	63·00	3 3 0
TOTAL	7215	—	335·3	£16 15 3½

Exercise D.

(1) During the month of April, patrons *A*, *B*, and *C* supplied 780, 1000, and 970 lb. of milk, testing 4·7, 3·9, and 4·3 per cent. respectively. If butter-fat is at a shilling per pound, what sum is due to each patron at the end of the month?

(2) During the months of October, November, and December, a certain farmer delivers 775, 860, and 940 lb. of milk, testing 3·9, 3·8, and 4·2 per cent. respectively. Calculate the total sum due to him for the three months' supply, butter-fat being worth a shilling per pound.

(3) During a certain month, *A* delivers 1200 lb. of milk testing 4·6 per cent., *B* 700 lb. testing 4·5 per cent., *C* 2000 lb. testing 3·9 per cent., and *D* 750 lb. testing 4 per cent. Eleven pence per pound is paid for butter-fat. The overrun is 16 per cent., and butter is sold at a shilling per pound. Find (*a*) the sum due to each supplier; (*b*) the total amount of butter made from the four lots of milk; (*c*) the profit derived from the sale of that butter (neglecting cost of manufacture).

E. Computing Averages.

As a general rule, the average of a number of records is obtained by finding their sum and dividing it by the number of records.

EXAMPLE. On four successive days, 800, 780, 820, and 850 lb. of milk are supplied by a farmer. What is the average number of pounds?

The sum of 800, 780, 820, and 850 is 3250. The average, obtained by dividing this by 4, is $812\frac{1}{2}$ lb.

Exercise E.

(1) The milk of a Jersey cow was tested for butter-fat every morning for a week. The results were 4·6, 4·6 4·8, 4·95, 4·7, 4·8, and 4·7. Find the average test, supposing the weight of milk not to vary.

(2) Find the average fat test of this herd :

Spotty,	50 lb.	milk	testing	3	per cent.
Pansy,	40	,,	,,	3·5	,,
Jane,	40	,,	,,	4·2	,,
Mottle,	30	,,	,,	5	,,

(Find the total yield of milk, and the total number of pounds fat ; then calculate the percentage from these results. Owing to the variation in the yields of milk, the correct result cannot be obtained by simply finding the average of 3, 3·5, 4·2, and 5.)

(3) Find the average fat-test of this herd :

Cow No.	Pounds Milk.	Fat Percentage.
1	6500	4·2
2	8850	4
3	7050	3·5
4	9000	4·1
5	8800	5

(4) From the following totals, which show the amount of fat received and the price paid per pound during

six months, calculate the average price of fat per pound :

January,	10,000	pounds	at	11	pence	per lb.
February,	8,000	,,	,,	11	,,	,,
March,	7,000	,,	,,	$11\frac{1}{2}$	,,	,,
April,	6,000	,,	,,	12	,,	,,
May,	5,500	,,	,,	13	,,	,,
June,	5,000	,,	,,	13	,,	,,

Miscellaneous Exercises.

(1) How many pounds of 22 per cent. cream can be obtained from 3500 lb. of 4 per cent. milk, supposing no fat to be lost ?

(2) How many pounds of milk, testing 4·5 per cent. fat, would be required to yield $157\frac{1}{2}$ lb. of fat ?

(3) Find how many pounds of fat are in 84 lb. of skim-milk testing 0·03 per cent. fat.

(4) If the overrun is 16 per cent., how many pounds of butter can be made from 20 gallons of milk, testing 4 per cent.? (10 lb. milk = 1 gallon.)

(5) If 3600 lb. of 3 per cent. milk are mixed with 150 lb. of 28 per cent. cream, what percentage of fat does the mixture contain ?

(6) A certain quantity of 3 per cent. milk, when added to 20 lb. of 28 per cent. cream, made 500 lb. of a mixture testing 4 per cent. How many pounds of milk were used ?

(7) A cheese factory produces daily 10,000 lb. of whey, testing 0·32 per cent. fat. The fat is taken from the whey and made into whey butter, the overrun

being 12 per cent. If the butter is sold at a shilling per pound, what value of butter is made per day ?

(8) A farmer delivered 850 gallons of milk, testing 4·5 per cent. fat. If the approximate weight (10 lb.) instead of the exact weight (10·32 lb.) of a gallon of milk be used in calculating the weight of butter-fat, by how many pounds will the result be in error ?

(9) Supposing the overrun to be 16 per cent., how much butter can be made from 30 days' milk of 28 cows ?

10 of the	cows	give	40 lb.	daily	(4 per cent. fat).	
6	,,	,,	35	,,	(3·8 ,,	).
8	,,	,,	30	,,	(3·8 ,,	).
4	,,	,,	30	,,	(3·5 ,,	).

(10) 1000 lb. of 4 per cent. milk are produced on a farm each day. At first this is made into butter on the farm, the overrun being 12 per cent., and the price of the butter 10 pence per pound. It is afterwards sent to a creamery and paid for at the rate of a shilling per pound of butter-fat. Find how much is gained or lost per week by the change.

(11) If milk testing 4 per cent. fat is sold at 4 pence per quart, what should be paid per quart for cream testing 32 per cent. fat ?

(12) A creamery, receiving 900 lb. of fat daily, is making an overrun of 18 per cent. and selling the butter at a shilling per pound. The overrun is increased to 20 per cent., and at the same time, the price of the butter falls one penny per pound. How is the weekly income affected by the change ?

ANSWERS TO EXERCISES.

EXERCISE A. (1) 0·27 lb. fat; (2) 0·102 lb. fat; (3) 12·6 lb. of fat; (4) 80 lb. cream; (5) 33·024 lb. proteids (or 32 lb., assuming a gallon of milk to weigh only 10 lb.); (6) 2 cwt. 64·96 lb.; (7) 20 cows.

EXERCISE B. (1) 1s. 9½d. (approx.); (2) 7s. 9d.; (3) $\frac{1}{10}$ lb. fat; (4) 0·03 lb.; (5) 512·325 lb. of cream.

EXERCISE C. (1) 20 per cent. overrun; (2) 371·2 lb. butter; (3) £2 19s. 8·8d.; (4) 300 lbs. overrun; (5) £4 1s. 3d.

EXERCISE D. (1) *A* £1 16s. 8d., *B* £1 19s. 0d., *C* £2 1s. 8½d.; (2) £5 2s. 4½d.; (3) (*a*) *A* £2 10s. 7¼d.; *B* £1 8s. 10½d., *C* £3 11s. 6d., *D* £1 7s. 6d.; (*b*) 225·852 lb. butter; £2 7s. 4½d. profit.

EXERCISE E. (1) 4·735 per cent.; (2) 3·8 per cent.; (3) 4·18 per cent.; (4) 11¾ pence (nearly).

MISCELLANEOUS EXERCISES. (1) 636·36 lb. cream; (2) 3500 lb. milk; (3) 0·0252 lb. fat; (4) $9\frac{7}{25}$ lb. butter; (5) 4 per cent.; (6) 480 lb. milk; (7) £1 15s. 10d.; (8) 12·24 lb. fat; (9) 1298·04 lb. fat; (10) 18s. 8d. gained; (11) 2s. 8d.; (12) £25 4s. 0d. decrease.

represented on the Centigrade and Fahrenheit scales by 100 degrees and 180 degrees respectively. Consequently, a Fahrenheit degree is $\frac{100}{180}$ or $\frac{5}{9}$ of a Centigrade degree. This fact is made use of in converting degrees from one scale to the other.

To Convert from Centigrade to Fahrenheit.

Multiply degrees C. by $\frac{9}{5}$ and add 32. For example,

15 degrees C. $= 15 \times \frac{9}{5} + 32 = 59$ degrees F.

To Convert from Fahrenheit to Centigrade.

Subtract 32 from degrees F. and multiply the remainder by $\frac{5}{9}$.

For example, 167 degrees F.

$= (167 - 32) \times \frac{5}{9} = 75$ degrees C.

C. Degrees of Acidity.

	Per cent. acid.	
Milk	0·1	ordinary fresh milk.
Milk	0·2	limit for pasteurization.
Milk	0·2	add rennet in cheese-making.
Whey	0·2	curd ready for dipping.
Milk	0·3	limit for cheese-making.
Milk	0·4	sour to taste and smell.
Milk	0·5	slightly thick.
Cream	0·6	average churning-point.
Cream	0·65	limit for churning.
Whey	0·7	curd ready for milling.
Starter	0·85	best acidity for starter.
Milk	0·9	maximum acidity for milk.
Whey	1·0	curd ready for salting.

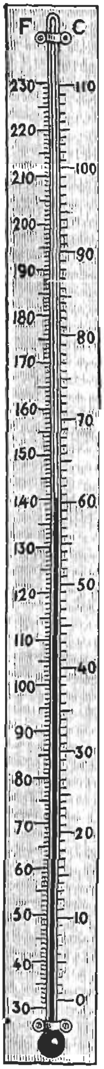

Fig. 81.- Fahrenheit and Centigrade Degrees.

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